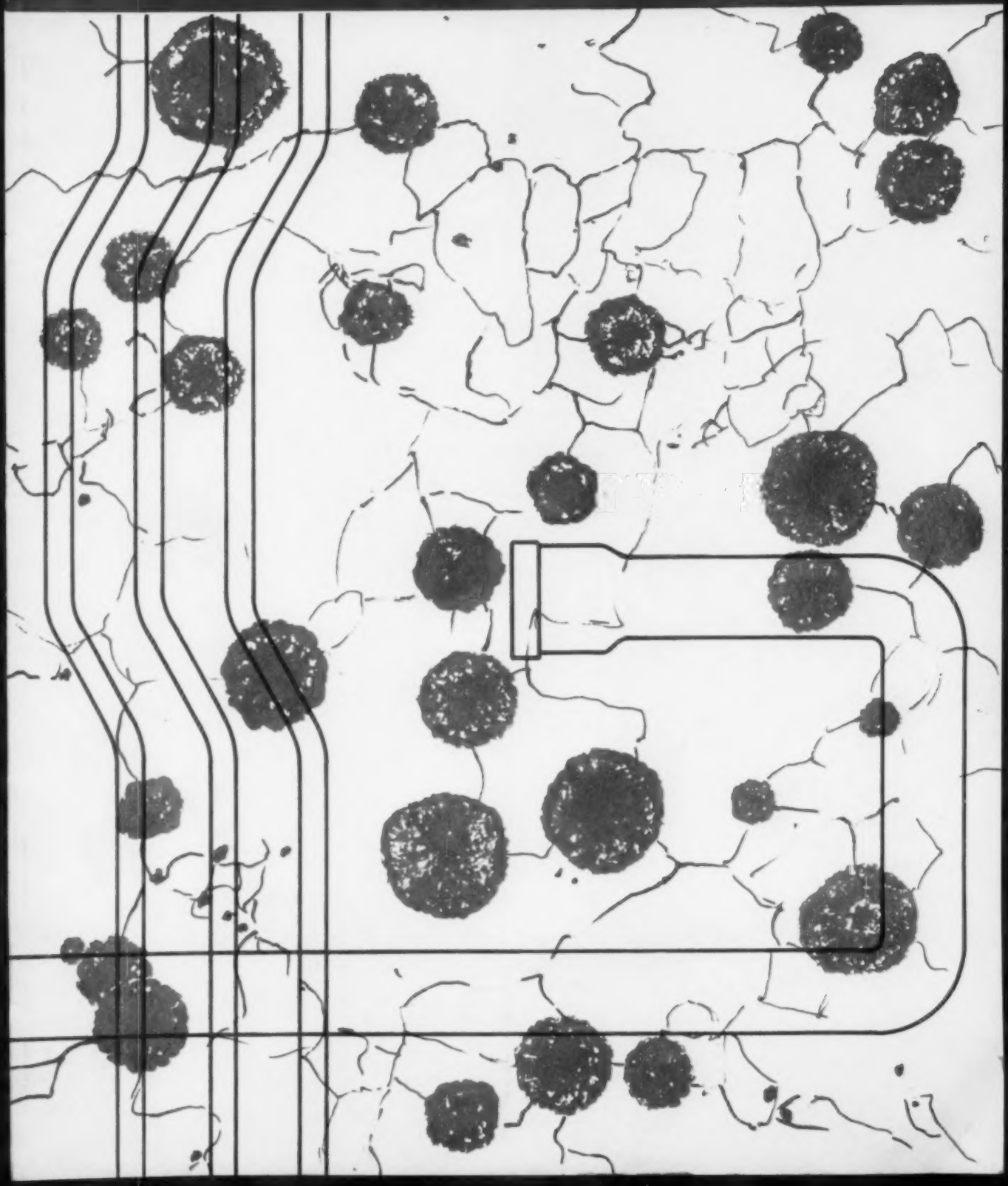
JOURNAL OF

METALS

JUNE 1960



One of a series

Higher Education for Computers

"Let's put the computer in at the start of a problem, rather than just having it buzz through the computations."

This is the approach being taken by computer specialists at the General Motors Research Laboratories as they explore ways of giving large-scale digital computers a greater role in the solution of problems. The object is to "teach" computers to apply the same rules men use in formulating, analyzing, and solving questions of modern science and engineering.

A recent outgrowth of this work is DYANA, GM Research's new automatic analysis and programming system. DYANA is one of the first computer systems to "understand" declarative statements. For a large class of dynamic problems, the engineer can simply describe his physical system to the computer. The computer figures out how to handle it.

For the solution, DYANA automatically directs the computer to prepare a mathematical model of the system, to write its own program for solving the model, then to execute the program and compute the desired answers.

The higher education of computers currently involves studies in symbol manipulation, problem-oriented languages, character and pattern recognition, and engineering simulation.

Such advanced computer concepts are giving General Motors professional people more time for creative engineering and research—time to explore ideas and to develop "more and better things for more people."

General Motors Research Laboratories

Warren, Michigan

Comparison of program tapes for a vibrational problem expressed in DYANA language, in algebraic-oriented language, and in the basic machine language.

JOURNAL OF

METALS

Vol. 12, No.6
June , 1960

COVER: Steel-like strength combined with ease of casting and resistance to corrosion . . . these qualities of ductile iron stem from the microstructure depicted on the cover by David Cain. . . . A review of the metallurgy and production techniques for ductile iron are featured in this issue beginning on p. 459.—Attention is also called to the 1959 Salary Survey of The Metallurgical Society starting on p. 455.

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personnel

● These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the societies of Civil, Electrical, Chemical Mechanical, Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 60% of the first month's salary if a non-member, 50% if a member. Also, that you will agree to sign our placement fee arrangement which will be mailed to you immediately after receiving your application. In sending applications be sure to list the key and job number. The New York office of Engineering Societies Personnel Service, Inc., is open for interviews until 7:00 p.m. Thursday evenings.

● When making application for a position, include eight cents in stamps for forwarding application to the employer and for returning, when possible.

—MEN AVAILABLE—

All those listed under "Men Available" have membership in the AIME.

Metallurgical Engineer with M.S. and 15 years in research, development, and process metallurgy. Strong background of theory and practice. Administrative and teaching experience. Desire challenging position on executive level. M-232.

Sales or Customer Service Engineer. B.S. Met. Eng. Chief metallurgist and supervisor of metallurgical and chemistry laboratories; materials and processes specification writing and application; failure analysis; sales experience; and vacuum treatment of steel. Prefer Cleveland or Midwest. M-233.

Process Metallurgist, B.Sc. (Eng) A.R.S.M. Two years research into thermoelectric materials manufacture. Prefer Philadelphia or New York area. M-234.

Metallurgist; B.S., M.S., Metallurgy, M.S. Bus Adm, age 25. Three years metallurgical research in aircraft and missile field; one year diversified foundry work; one year part-time instructor for foundry course. Locate anywhere. M-1093-Chicago.

Designer; MinE, age 59. Many years experience in design (structural, mechanical, civil) of ore treatment plants, large industrials and facilities, and sewage treatment and mining ore treatment plants. Was also in charge of fire and safety equipment. $7800. Prefer San Francisco. Se-545.

Metallurgist; B.S. Met, age 35. One year as research engineer doing mechanical analysis, planning and monitoring research programs for aircraft castings, forgings, and extrusion. Eight years supervising and directing chemical and test lab, plus product inspection for basic steel production. $10,800. Prefer Northwest or East coast. Se-304.

Metallurgist, Teacher; BSMin, EM Met, age 57. Twenty years experience. Built mills; was superintendent and manager over metal mining and milling. Two years sales of fuel additives for chemicals manufacturer. One year associate professor of mining and metallurgy. $6000. Locate anywhere. Se-1772.

Supervisor; graduate MinE, Met, age 55. Thirty years experience in examination, exploration, development, and operation of nonferrous metal mines, mills, and allied fields. Licensed professional engineer. $7800. Prefer West. Se-1580.

Metallurgist; MetE. age 43. Three years in applied mineral beneficiation research and pilot plant operations (industrial waste and non-sulfide ore). Selective flotation and cyanide plant operational experience. Lead smelter two years. One year of aircraft company titanium and super-alloys. Assay experience on gold and base-metal ores. Salary, open. Prefer West, Northwest. Se-593.

—POSITIONS OPEN—

Address replies for positions to the nearest local office of the Engineering Societies Personnel Service, Inc., *not* to the JOURNAL OF METALS. Offices are located at 29 E. Madison St., Chicago 1, Ill. . . . 57 Post St., San Francisco, Calif. . . . and 8 W. 40th St., New York 18, N. Y.

Metallurgist; young graduate for research and development programs on new alloys. Should have from three to five years experience in physical metallurgy development work covering a fairly wide variety of ferrous or nonferrous materials. Experience in large organization with broad range of assignments desirable. Salary, open. Location: East. W8973.

Sales Engineer; degree or equivalent, with preferred emphasis in chemistry or metallurgy or chemical or metallurgical engineering. Should have minimum of three years in metallurgical or chemical sales or engineering, or other closely related activity. To promote use of and sell chemical, ceramic, metallurgical, and other products to a variety of industrial accounts. Travel approximately 60 pct. Apply by letter giving complete information, including current salary and expected salary. Headquarters: Pa. W8933.

Metallurgist or Ceramist; B.S. or M.S. in metallurgy or ceramics, with one to three years research experience, preferably in powdered metals or ceramics. To conduct research in the field of sintered metal and metal-ceramic combinations, mainly for friction and bearing applications. Will make theoretical analysis of metallic and metallic-ceramic systems to develop alloys and mixtures that have unique heat-resistance and strength properties. Starting salary to $8000. Company pays placement fee. Location: northern N. J. W8929.

Manager; graduate mechanical or metallurgical engineer with knowledge of alloys. To manage small concern extruding phosphor copper alloys. Should be well versed in extrusion presses, wire drawing, and billet casting and have knowledge of copper alloys. Salary, $10,000. Location: Westchester County, N. Y. W8911.

Engineer with metal working or chemical engineering degree and minimum of five years metal finishing experience, preferably in organic enameling, plating, anodizing, and finishing problems in general. Desire experience with small components. Salary, $11,000. Location: Pa. W8888.

Metallurgist; B.S. to Ph.D. Must have several years experience in research in phase diagram and isothermal transformation studies for research organization. Salary, $7200-$10,800. Employer will negotiate fee. Location: Ill. C7812 (d).

Pilot Plant Superintendent; Met or MinE experienced in pilot plant ore dressing operations (heavy media, jigging, spirals, flotation, magnetic separation) for iron ore operation. Must have working knowledge of Spanish. Possible family housing after employment, after two to three months single status. For an open pit mine operation. About $9600, plus benefits. Location: South America. Sj-5210.

Junior and Senior Design Engineers; MinE, MetE, CE, or ME degree. Require background in industrial design and drafting, with previous experience in mining, milling, smelting, or refining plants and facilities desired. Applicants for positions at junior level especially desired, but some seniors also. Salary, $7200-10,200 plus benefits. Headquarters: Utah. Sj-5174-R.

Metallurgist or Chemist; Chem, Met-Chem or Met for work in analytical lab and extractive metal research. Degree, several years experience, and ability for research is desired. Salary, open. Location: Mont. Sj-5139.

a) **Sales Manager;** metallurgical training and five or more years experience as sales manager contacting steel plants and foundries. Must know steel operations . . . steel making and combining of alloys . . . market on scrap metals and alloys, warehousing and shipping facilities in steel plants . . . and be able to negotiate price, depending on amounts, tonnage, and deliveries. Duties: Selling engineering services, contacting engineers and operators in steel plants and foundries selling ferro-chrome. Product is highly competitive. Salary, about $15,000, plus bonus. Headquarters: Chicago.

b) **Salesmen** on above for Chicago, Pittsburgh, Cleveland, Detroit, Southwest, and West. $10,000. Employer will negotiate placement fee. Sj-5133.

Engineers. a) Metallurgist for R&D. To develop new uses in the rare earth field. b) Application engineer, chemist, metallurgist, or physicist having some contact with materials used in electronic vacuum tube parts. Salaries, open. Location: northern N. J. W8845.

Metallurgist. Graduate with approximately three years industrial experience. To assist chief metallurgist in evaluating incoming materials, assist production, and develop new equipment in connection with magnetic materials, nickel iron, and silicon iron alloys for tape and bobbin cores. Salary, about $8500. Location, southern N. J. W8827.

Sales Trainee for metals sales division. Recent graduate in metallurgical, chemical, or mechanical engineering with desire to enter the field of industrial sales. Minor travel during training period. Headquarters: New York City. W8817 (b).

Metallurgical or Mechanical Engineers for line supervisory positions. Must have foundry background and be heavy on steel. a) Quality Control Manager. b) Assistant General Foreman in charge of cleaning room. c) Assistant General Foreman to run grey iron foundry. Salaries, $7800-$10,000. Location: Pa. W8860.

Sales Engineer; graduate with minimum of five years foundry or other industrial experience relating to metallurgy. Will provide technical sales assistance on ferrous castings and in-plant responsibility for metallurgy or production and applied research and development. Ferrous foundry. Salary, $7200 to $9600. Location: San Francisco East Bay. Sj-5090.

Associate Editor for trade publication. Experience in metal working. Some experience in writing. Salary, about $7200. Location: New York City. W8846.

NEW BULLETIN

A new bi-weekly bulletin of "Engineers Available" is now being published by the Engineering Societies Personnel Service, Inc. Distributed free of charge, the bulletin contains synopses of the experience of engineers who have registered with the Service and are seeking a new position.

Any employer interested in receiving the bulletin should so advise E.S.P.S. at 8 W. 40th St., New York 18, N.Y., and your name will be placed on the mailing list. Any engineer who is registered with the Service or wishes to register is entitled to a 35-word notice in the bulletin. Write to the New York office for forms. Your qualifications will be brought to the attention of employers on our mailing list without revealing your identity.

It is planned to extend the publication to the midwestern and western offices in the near future.

Whether furnace output is measured in grams or tons, Hevi-Duty's value solution pays steady operating dividends.

When you consult a Hevi-Duty Sales Engineer on any heat-processing problem, you take three important steps toward a sound solution. For Hevi-Duty helps you three ways:

Designs the system to fit your need. A Hevi-Duty Applications Engineer works full time on such problems. Call on him. He might save you countless hours. He may have solved a problem like yours last week.

Designs the furnace to fit the system. Usually, the unit you need will be a proven item, for you are drawing from the most complete line of heat-processing equipment in the business. If not, Hevi-Duty engineers can quickly design the unit that fits your needs exactly.

Builds the furnace to last. Hevi-Duty furnaces are built for tough, continuous production work. They are designed to last, and hundreds of case histories prove they do.

Here are three typical examples of non-ferrous melting furnaces spanning a wide range of sizes, yet each provides the value solution to a problem.

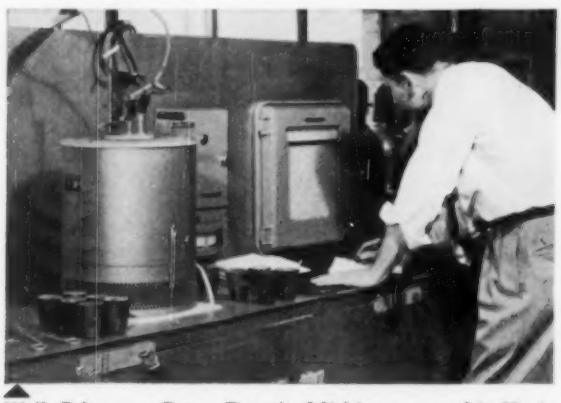
HEVI-DUTY

Electric and Fuel-Fired Industrial Furnaces and Ovens

B P C

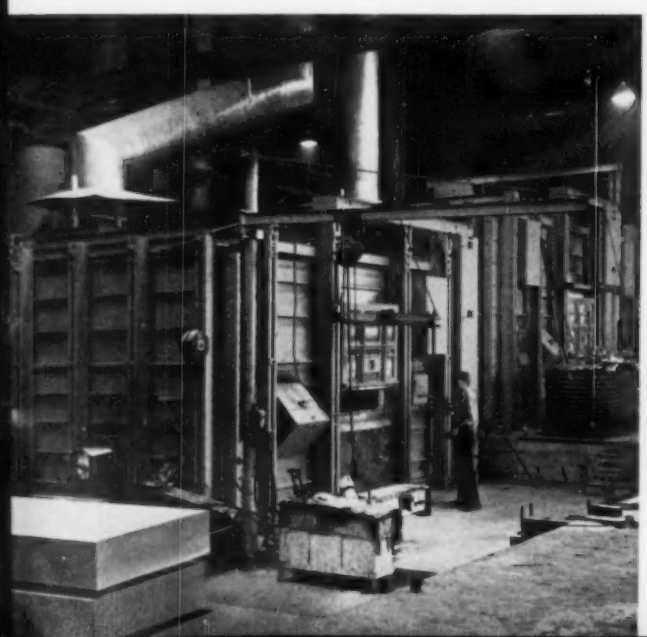
A Division of Basic Products Corporation

Hevi-Duty Electric Company, Milwaukee 1, Wis.



Wall Colmonoy Corp., Detroit, Michigan, uses this Hevi-Duty laboratory crucible furnace to find exact melting temperatures of hard-surfacing and brazing alloys. Furnace heats rapidly to the 2200° F. temperature required, provides precise control for melting and cooling tests on 250 g samples. User reports long element life at high temperatures. ***For more information, send for Bulletin 1246.***

This Hevi-Duty double-chamber, dry-hearth furnace melts 100 lb of aluminum per hour, 16 hours a day, 7 days a week at Alliance Mfg. Co., Alliance, Ohio. It can provide up to 200-lb-per-hour output and occupies little space. It maintains critical bath temperatures during charging. User states: "You can turn it on and forget about it." ***For complete information, send for Bulletin 593.***



Kawneer Company, St. Charles, Illinois, has installed a second pair of Hevi-Duty reverberatory furnaces for breakdown and holding in direct-chill ingot casting of four different alloys. Furnaces provide ± 10° F. control, pour at 1320° F., operate 24 hours a day. Capacity is 100,000 lb a day. Note in the foreground two of the 6,300-lb aluminum ingots produced. ***Please write for Bulletin 591.***

KELLOGG ENGINEERS AND BUILDS FOR KENNECOTT

KENNECOTT'S NEW $30-MILLION COPPER REFINERY DEMONSTRATES KELLOGG'S ECONOMIC APPROACH TO PLANT ENGINEERING, PROCUREMENT, CONSTRUCTION

Kennecott's new plant in Anne Arundel County, Maryland, is the newest and most modern electrolytic copper refinery in the United States. A model of efficient and economical execution, it is the result of close teamwork between Kennecott Refining Corporation and The M. W. Kellogg Company—to whom Kennecott assigned over-all responsibility for engineering, procurement, and construction.

This $30-million project demonstrates how large and complex plants can be designed and built for the optimum *predetermined* investment when all phases of the job are integrated into one unified operation by a single contractor. The method and the results are typical of the way Kellogg has worked with leading oil refiners, chemical companies and ore beneficiating firms.

Many design and engineering innovations resulted from this relationship. Among them were various ways to facilitate materials handling and expedite product flow. These included: a specially designed automatic anode take-off machine; straddle trucks for moving cathodes; and semi-automatic bundling for copper billets. Plant construction also was speeded by Kellogg, and erection costs cut, by production-line pouring—right in the plant—of 1,000 huge concrete cells, and by training workers on the spot to fabricate over 95,000 feet of plastic pipe at the plant site.

The complete story of Kellogg's engineering-procurement-construction assignment for Kennecott is available to you in a 12-page folder. You are also invited to send for Kellogg's brochure—"Planning the New Plant for Profits".

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17

A SUBSIDIARY OF PULLMAN INCORPORATED

Offices of Kellogg subsidiary companies are in Toronto, London, Paris, Rio de Janeiro, Caracas, Buenos Aires

Below is the new electrolytic copper refinery of Kennecott Refining Corporation (a subsidiary of Kennecott Copper Corporation) in Anne Arundel County, Maryland. Engineered and built by The M. W. Kellogg Company, this plant is expected to have a monthly capacity of 16,500 tons of 99.95% purity copper by mid-July.

new books

Books that are marked (•) may be ordered through AIME. Address Irene K. Sharp, AIME Book Dept., 29 W. 39 St., New York 18, N. Y. A discount is given whenever it is possible.

Cobalt Information

► A new publication on magnetostriction phenomena in cobalt and cobalt alloys is available from the Battelle Memorial Institute's Cobalt Information Center. The 60-pp. document outlines the reciprocal and nonreciprocal mechanical and magnetic effects on ferromagnetic materials produced by magnetization. More than 125 references to magnetostriction effects in cobalt and its alloys are listed, covering technical literature from 1847 through mid-1959. Interested persons should make their requests on company letterhead to: Cobalt Information Center, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio. Foreign requests should be directed to Centre d' Information du Cobalt, 35, rue des Colonies, Brussels, Belgium.

ASTM Standards on Copper and Copper Alloys, *American Society for Testing Materials*, 704 pp., $7.50, 1959—Included in this special compilation is information on nonferrous materials for electrical conductors and for use in copper-alloy products •

Thermochemistry for Steelmaking, Vol. 1, by John F. Elliott and Molly Gleiser, *Addison-Wesley Publishing Co. Inc.*, 269 pp., $10.50, 1960—This volume is the first of several to be issued containing a collection of tables and charts on the high-temperature chemistry of iron and steelmaking. This volume contains basic physical and thermochemical properties of selected elements . . . standard heats and free energies of formation of inorganic carbides, nitrides, oxides, phosphides, and silicides . . . and the vapor pressures of selected elements and compounds on the Kelvin temperature scale. Tabular data are extrapolated to 3000°K, and thermochemical properties extrapolated assuming C_p is constant above 2000°K. •

Materials in Space Environment: Proceedings of the Fifth Sagamore Ordnance Materials Research Conference, by the *Office of Technical Services*, 276 pp., $4, 1959—This proceedings volume contains 18 papers, plus formal lectures, and transcripts of informal discussions. Covered are such topics as space environment and vehicle requirements . . . physics of space vacuum and effects on materials . . . thermal problems under orbiting conditions . . .radiation and radiation effects in outer space . . . meteorites and cosmic dust in space . . . and implications of space environment for material development.

Government, industry, and university participants are all connected with some phase of metallurgical research or applications related to the field. Refer to *PB 151900* when ordering from the *Office of Tecnical Services, US Dept. of Commerce, Washington 25, D. C.*

The Welding of Titanium and Titanium Alloys, by G. E. Faulkner and C. B. Voldrich, Defense Metals Information Center, Battelle Memorial Institute. This report is an updating of findings published in 1956. It indicates the following progress in the field: 1) fabricators have started using inert-gas-shielded metal-arc welding operations in production; 2) alloys have been used to a greater extent in welded assemblies; 3) a great deal of information concerning the engineering properties of welded joints in some of the alloys has been developed; and 4) titanium has been approved as a material of construction for unfired pressure vessels.

Copies of the paper, labeled PB 151079, may be obtained through the *Office of Technical Services, US Dept. of Commerce, Washington 25, D. C.*

Structural Damage in Thermally Cycled René 41 and Astroloy Sheet Materials, by D. P. Moon, J. A. Van Echo, and W. F. Simmons, of Battelle Memorial Institute, and J. F. Barker, General Electric Co. Stress-rupture life at 1650°F and tensile properties at room temperature and at 1400°F were used to determine the extent of structural damage in thermally cycled René 41 and Astroloy sheet materials. Solution-treated and aged René 41 was tested both in the heat-treated condition and after exposure to 10 or 100 thermal cycles between 1350°F and 1750° or 1875°F. All of the conditions of thermal-cycling exposure caused at least some loss in the strength of this material. Metallographic examination indicated that overaging was primarily responsible for the damage at 1750°F, and resolution of the Ni_3 (Al, Ti) precipitate and depletion of the alloy by surface oxidation were the damaging mechanisms at 1875°F.

Solution-treated and aged Astroloy was evaluated in the same manner in the heat-treated condition and after 10 thermal cycles between 1350°F and 1875°F. No loss of strength was incurred by this exposure, but overaging had taken place and would probably have caused structural damage with further exposure.

Copies of PB 151083 may be obtained through the *Office of Technical Services, US Dept. of Commerce, Washington 25, D. C.*

Methods for Conducting Short-Time Tensile Creep, and Creep-Rupture Tests Under Conditions of Rapid Heating, by Donald P. Moon and Ward F. Simmons, Battelle Memorial Institute. The need for very short-

(Continued on page 434)

Metallurgists: BS or MS degree in metallurgy, with two to five years experience in alloy development, phase diagrams, physical property determinations of nonferrous metals. Will be responsible for carrying out research programs on beryllium containing alloys. Salary open. Location Reading, Pennsylvania.

Box 8-JM.

Research Metallurgist

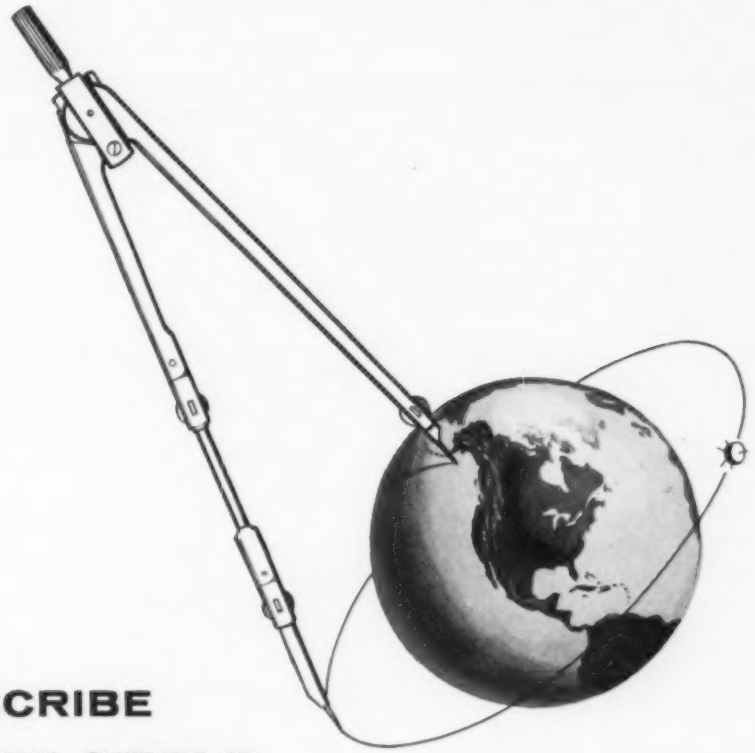
Opportunity with large Western Pennsylvania research and development organization for PhD with experience. Physical metallurgy research on the effect of chemical composition, hardenability, heat-treating variables and microstructure, including grain boundry constituents, on desired properties of alloy steels. Reply giving complete information and salary requirements to Box No. **11-JM.**

PROJECT SUPERVISOR: Ph.D., or equivalent degree, in metallurgy possessing at least 3 years experience in alloy design and development on a research level. To act as project supervisor in the investigation of new or improved beryllium containing alloys in a broad basic research program. Salary open. Location Reading, Pennsylvania.

Box 9-JM.

Physical Metallurgist

Opportunity in large Western Pennsylvania research and development organization for recent BS or MS graduate having sound educational background in physical metallurgy. Applicants with knowledge of X-ray diffraction and metallography preferred. Experience desirable but not essential. Reply giving complete information and salary requirements to Box No. **12-JM.**



HOW TO SCRIBE A "PERFECT" CIRCLE IN OUTER SPACE

Bell Laboratories guidance system achieves unprecedented accuracy in steering Tiros weather satellite into orbit

Equipped with TV cameras, tape recorders, solar cells and antennas, the world's most advanced weather satellite, the NASA Tiros I, had to be placed in a precisely circular orbit at a specified altitude to do its job well.

The "shot" was a virtual bull's-eye. The mean altitude was within *one mile* of that planned. And the deviation from this mean was less than ½ per cent, making it the most-nearly-perfect circular orbit ever achieved with a space vehicle by either the United States or Russia.

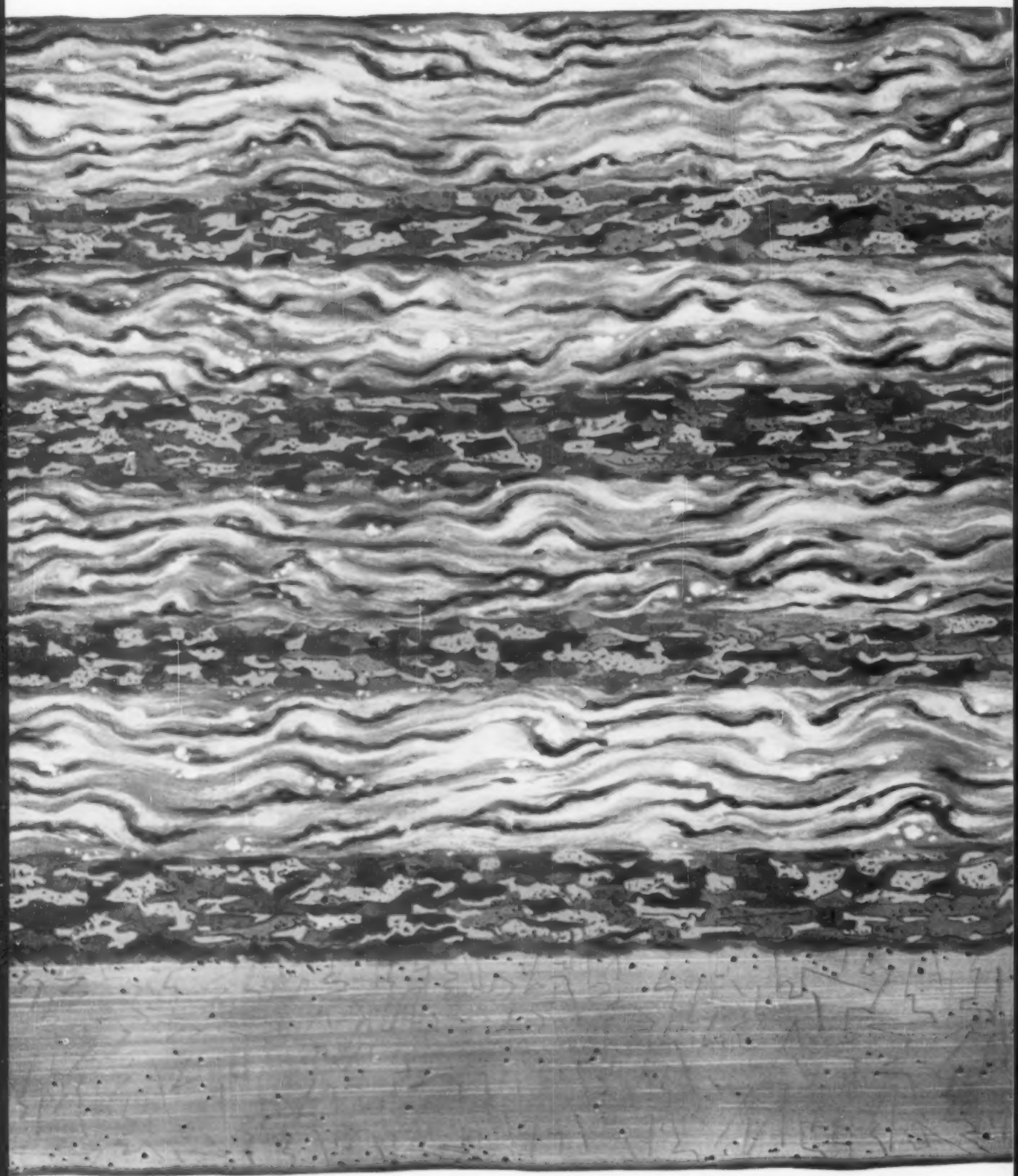
Two Bell Laboratories engineers, T. J. Grieser and D. R. Hagner, look over the second-stage section of the Air Force Thor-Able missile used to launch the NASA Tiros weather satellite.

The dependability and accuracy of Bell Laboratories' ground-controlled Command Guidance System has been proven before—in the successful test flights of the Air Force Titan intercontinental ballistic missile, and in last year's Air Force Thor-Able re-entry test shots from which the first nose-cone recoveries were made at ICBM distance. Now, with Tiros, the system contributes to a dramatic *non*-military project. Other uses are in the offing.

This achievement in precise guidance again illustrates the versatility of Bell Laboratories' research and development capabilities—directed primarily toward improving your Bell Telephone service.

BELL TELEPHONE LABORATORIES

World center of communications research and development



Thermal Protection Systems: No single material possesses the range of complex properties necessary to withstand the high temperatures of missile and space requirements. To solve this problem, composite materials and structures that combine the desirable characteristics of several materials, are being developed. Some of these approaches include insulating layers and heat sinks; transpiration, film or liquid-metal cooling; ablation and sublimation coatings. Shown is an artist's rendering of an insulating, composite material made up of extremely thin layers of metal and ceramics which promises to be very efficient in protecting against high-heat environments. Development of such systems is considered at Lockheed to be an integrated relation of materials, environment and design.

METALLURGY

EXPANDING THE FRONTIERS OF SPACE TECHNOLOGY

Metallurgy is typical of Lockheed Missiles and Space Division's broad diversification. The Division possesses complete capability in more than 40 areas of science and technology—from concept to operation. Its programs provide a fascinating challenge to creative engineers and scientists. They include: celestial mechanics; computer research and development; electromagnetic wave propagation and radiation; electronics; the flight sciences; human engineering; magnetohydrodynamics; man in space; materials and processes; applied mathematics; oceanography; operations research and analysis; ionic, nuclear and plasma propulsion and exotic fuels; sonics; space communications; space medicine; space navigation; and space physics.

Engineers and Scientists—Such programs reach far into the future and deal with unknown and stimulating environments. It is a rewarding future with a company that has an outstanding record of progress and achievement. If you are experienced in any of the above areas, or in related work, we invite your inquiry. Please write: Research and Development Staff, Dept. F-55, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense industrial security clearance required.

Lockheed

MISSILES AND SPACE DIVISION

Prime Contractor for the Navy POLARIS FBM; the Air Force AGENA Satellite in the DISCOVERER, MIDAS and SAMOS Programs; Air Force X-7; and Army KINGFISHER

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BOOKS

(Continued from page 430)

time, high-temperature tensile and creep data for the design of supersonic aircraft and missiles has led to the development of a group of rapid-heating tests. These tests are of relatively brief duration, often only 1 or 2 sec. They require special equipment and techniques for the rapid heating of test specimens and for the accurate measurement and control of temperature, stress, and strain during test.

In addition to very short-time constant-temperature tensile and creep tests after rapid heating, this group of tests includes those in which preloaded specimens are heated rapidly until rupture or are heated to a test temperature for the determination of time for a given deformation or for rupture.

The equipment and test methods used by 15 different organizations in conducting tests involving rapid-heating methods are reviewed in this report. A wide variety of testing methods are being used by these organizations because of the equipment available for the testing and the type of data desired. The more important variations in equipment and technique are described in detail. The main advantages and disadvantages of the various techniques are discussed, and applicable requirements of ASTM-recommended practices are cited.

The methods used for the rapid heating of test specimens include resistance, induction, radiant, and hot-fluid heating. These are described in detail, along with methods for controlling specimen temperature. The role of speciman design is discussed, and several speciman contours are illustrated. The spot welding of thermocouples, the calibration of radiation pyrometers, and the merits of various types of load cells, strain extensometers, and recorders are also covered in this report.

Although no formal conclusions are presented in the report, the wide variety of test practices in use for conducting rapid-heating tests suggests the need for standardization of procedures.

Copies of the report, PB 151078, may be obtained from the *Office of Technical Services, US Dept. of Commerce, Washington 25, D. C.*

Oxidation Behavior and Protective Coatings for Columbium and Columbium-Base Alloys, by W. D. Klopp, Defense Metals Information Center, Battelle Memorial Institute. Among this report's findings are these—Four phases occur in the columbium-oxygen system: Cb-O solid solution, CbO, CbO_2, and Cb_2O_5. The solid solubility of oxygen in columbium is appreciable, but available data on the solubility-temperature relationship are in conflict. CbO and CbO_2 melt congruently at 1945°C and 1915°C, respectively. Cb_2O_5 melts at about 1500°C and can vary in oxygen content from about 70 to 73 atm pct. Six forms of Cb_2O_5 are reported: amorphous, δ (a partially crystallized form of γ), γ, β (a partially crystallized form of α), α, and a high-temperature form.

At low temperatures and oxygen pressures, the columbium-oxygen reaction proceeds at a very low linear rate, and no scale is formed. At slightly higher temperatures and pressures, an unidentified adherent

(Continued on page 436)

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BOOKS

(Continued from page 434)

scale forms and the reaction proceeds parabolically. Parabolic behavior is followed in air to about 400°C, accompanied by formation of a visible tarnish film. At 400° to 500°C, microscopic blisters of porous Cb_2O_5 erupt on the surface of the adherent tarnish film, and the reaction kinetics change from parabolic to linear. In the temperature range 500° to 700°C, the variation of the linear reaction rate with temperature is a subject of disagreement, but above 700°C, the rate increases rather rapidly with temperature. The scale formed at these temperatures consists of porous Cb_2O_5 overlying a thin adherent layer of oriented Cb_2O_5 containing traces of CbO. A tendency for the porous Cb_2O_5 to sinter has been noted at about 900°C and above. In 1 atm of oxygen, the columbium-oxygen reaction becomes catastrophic at 1400°C.

Pure nitrogen reacts slowly with columbium to form an adherent nitride film at temperatures up to 1600°C. In air, nitrogen has no apparent effect on the oxidation reaction except as a diluent for oxygen.

Contamination of columbium metal during oxidation in both air and oxygen is appreciable due to the high solubility and diffusion rate of oxygen in columbium. The depth of contamination and accompanying embrittlement may easily exceed the amount of metal consumed by oxidation.

Binary alloy additions which effectively improve the oxidation resistance of columbium include chromium, molybdenum, titanium, tungsten, vanadium, and zirconium. These elements, when added in the optimum amount, reduce the rate at 1000°C by about tenfold, and at 1200°C by about sixfold. Titanium and zirconium also reduce the depth of contamination by about tenfold by reacting with the inward-diffusing oxygen and precipitating to form an internal scale.

Additional significant improvements in oxidation resistance can be effected by ternary and higher alloying. The most oxidation-resistant tenary systems, based on available data, are as follows (in order of decreasing oxidation resistance):

Cb-Cr-Al; Cb-Fe-Al; Cb-Mo-Al; Cb-Ti-Al; Cb-Ti-Cr; Cb-Cr-Co; Cb-Mo-Cr; Cb-Fe-Co; Cb-Ti-Mo; Cb-Ti-V; and Cb-Cr-Ni.

Alloys in the first three systems are equal to or better than the popular Fecral alloy (Fe-25 wt pct Cr-5 wt pct Al) in high-temperature oxidation resistance, but compositions of the better alloys are in ranges where brittle intermetallics are expected to form.

Information on oxidation-resistant coatings for columbium is rather limited. Coatings of LM-5 and a modified nickel-chromium alloy have shown promise.

It appears that, although oxidation-resistant compositions are being developed, useful high-strength columbium alloys will require coatings for service in oxidizing atmospheres.

Order the report, PB 151080, from the *Office of Technical Services, US Dept. of Commerce, Washington 25, D. C.*

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Harry G. Papacharalambous and **Robert L. Wasson** will be in the Development Dept. of The Carborundum Co.'s new technical building, when it is completed in June. The $750,000 technical building at Niagara Falls, N. Y., will include new laboratories and offices for its technical personnel.

Henry J. Fisher has been named manager of alloy development for the Technical div., The Beryllium Corp. Dr. Fisher joined Berylco from the General Electric Co., Schenectady, N. Y., where he was a research physical metallurgist. At Berylco he will be responsible for research and development projects pertaining to beryllium alloys.

Andrew Fletcher is now chairman of the board, St. Joseph Lead Co. President of St. Joseph Lead since 1947, Mr. Fletcher has long been active in the AIME. He is currently president of the United Engineering Trustees Inc.

Theodore E. Dann is now general supt. of the Charleston, S. C., plant of Pittsburgh Metallurgical Co. He was formerly at the Co.'s Calvert City, Ky., plant.

William H. Finkeldey has moved up from president to chairman of the board, Singmaster & Breyer Inc., New York City affiliate of The Fluor Corp. Ltd. **Byron Marquis** succeeds him to the presidency. Mr. Marquis was formerly vice president of engineering.

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C. A. Lovgren is now assistant to the president of Swindell-Dressler Corp. Mr. Lovgren comes to the Pittsburgh firm from National Carbon Co., with whom he was based in New York City as a division manager.

Walter C. Bennett has retired as chairman of the Phelps Dodge Refining Corp., subsidiary of Phelps Dodge Corp. Mr. Bennett joined Nichols Chemical Co., which later became the Phelps Dodge Refining Co., in 1898.

Frederick D. Delve, formerly research engineer in Jones & Laughlin Steel Corp.'s Graham Laboratory, has been named supervisor of the Steel Works div. in the Metallurgical dept. of the Pittsburgh works.

Stanley Abkowitz takes the post of manager of refractory metals product development in Kelsey-Hayes Co.'s Metals div. He comes to Kelsey-Hayes from Mallory-Sharon Metals Corp., Niles, Ohio, where he was manager of materials and process development. Mr. Abkowitz's new assignment will be the development of new products for use at ultra-high temperatures.

Andrew J. Griest has joined the recently-formed Alloy Development section of the Basic Research dept., Allegheny Ludlum Steel Corp.'s Research Center at Brackenridge, Pa. Dr. Griest's title is senior research metallurgist, and he will be engaged in new alloy development in magnetic materials. He was formerly assistant division consultant at Battelle Memorial Institute.

Howard F. Taylor, professor of metallurgy, Massachusetts Institute of Technology, recently received recognition when *The New York Times* publicized some of his work in art casting. Working with Boston sculptor, Alfred M. Duca, Dr. Taylor achieved a 400-lb bronze casting of the mythical horse Pegasus. The casting technique developed by the men employs a self-destroying mold making use of polystyrene. After the sculptor carved the horse's shape from the plastic it was packed in a sand mold. The plastic vaporized when the molten metal was poured into prepared channels. The technique is simpler and less costly than other art casting methods, they find. Since the molten metal completely displaces the molded form, it can also retain the vitality of the original better than reusable casting techniques. However, because it is self destroying, industrial usage is not feasible

Charles T. ("Chick") **Greenidge** and **"Mike" Nestor** recently celebrated their 25th anniversaries with the Battelle Memorial Institute. Mr.

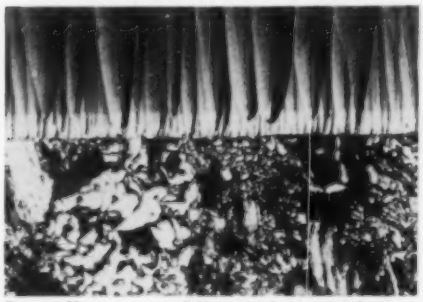
(Continued on page 445)

'Biggest' pyrolitic graphite made

The world's largest piece of pyrolitic graphite is among the latest claims made by the General Electric Research Laboratory. The piece is ⅛ in. thick x 17 x 31 in.

Pyrolitic graphite, which has recently aroused interest because of its ability to withstand extremely high temperatures, is stronger and more resistant to oxidation than ordinary graphite. The material is expected to find application in missile nose cone heat shields, rocket engine nozzles, and the steering vanes of missiles. It may find industrial application as a heat-resistant material in melting crucibles for metals, ceramics, and semiconductors. Another possible use is for slowing down neutrons in nuclear recators.

The heat resistance of pyrolitic graphite results from its atomic structure, in which graphite crystals are arranged in orderly stacks and layers (see picture).



In ordinary graphite, such crystals are embedded at random in a substance called a *binder*. Heat travels hundreds of times more easily along the layers of pyrolitic graphite than through them. Other characteristics of pyrolitic graphite, such as strength and corrosion resistance, also vary sharply depending upon the direction in which they are measured.

Pyrolitic graphite is hard, dense, and silvery-gray—slightly heavier than ordinary graphite. Above 3000°F it has the highest strength: weight ratio of any high-temperature material now being considered for practical use. Above 5000°F it has a tensile strength of approx 40,000 psi, compared to less than 1000 psi for tungsten.

Pyrolitic graphite's flexural strength—measured in the favorable direction—is approx 25,000 psi, while that of ordinary graphite ranges from 1000 to 8000 psi. Because of its high density, sheets only 1 or 2 mils thick are impervious to liquids and gases. As a result of its low chemical activity, it is also many times more resistant to oxidation than is conventional graphite. The characteristics of pyrolitic graphite are also said to be dependably reproducible, in contrast to graphite's variance from batch to batch.

Production of pyrolitic graphite is being developed by GE's William H. Smith, based on research conducted by Russell J. Diefendorf and Edward R. Stover. The production method involves placing a heated piece of commercial graphite in a stream of hydrocarbon, e.g., methane. The carbon in the gas is deposited on the surface of the original sample, while the hydrogen passes off. As the new material grows, crystals of graphite—composed of carbon atoms—form with their flat planes parallel to the existing surface. Before long, an almost homogeneous structure has built up, consisting of close-packed columns of graphite crystals. These crystals are joined to each other, along flat planes, by strong bonds.

Sideboard saves 6 pct metal

A new pouring procedure utilizing sideboards instead of hot tops is said to result in a 6 pct saving in metal. The sideboards were developed by Pittsburgh Metals Purifying Co. Inc. for Allegheny Ludlum Steel Corp.'s Brackenridge, Pa., plant.

The procedure eliminates hot tops by substituting two exothermic sideboards made to fit along the two opposing sides in the heads of big end down slab molds.

In tests on 40 ingots, a 6 pct increase in steel per ingot has been achieved, according to Richard B. Shaw, superintendent of melting. The pouring method is also said to simplify handling, reduce track time, and increases mold life, besides using big end down molds, which are faster and easier to strip than big end ups. Ultrasonic tests show the steel to be sound in every respect.

One man can handle the sideboards, rather than depending on a crane for hot topping. Another important advantage is that mold inventories can be reduced through the elimination of big end up molds.

French firm considering RN

Usines Schneider, the French heavy equipment producer, is reported to be considering installation of an RN direct iron ore reduction plant in the region of Marseilles. The plant would be used for processing red mud from alumina plants into a material suitable for steelmaking. A rotary-kiln sulfuric-acid plant used in munitions production some years ago is the contemplated site. If plans materialize, it would be the world's first commercial RN reduction plant.

New thermoelectric alloy

Development of a new semiconductor material—claimed to have the highest efficiency of any thermoelectric alloy, and the first to be commercially available in mass production quantities—has been announced by General Thermoelectric Corp. of Princeton, N.J.

Called *Neelium*, the new semiconductor material is quaternary alloy consisting of bismuth, tellurium, selenium, and antimony. According to the company, a typical figure of merit for Neelium is $Z = 3 \times 10^{-3}$, measured with the hot junction at + 55°C. Other pertinent values: thermoelectric power: 184 μv per degree; electrical conductivity: 1400 mho per cm; thermal conductivity: 3.8×10^{-2} per cm-sec-°C. A module consisting of eight Neelium thermocouples can be used in cooling high-power transistors, microscope and microtome tables, vacuum cold traps, dew-point hygrometers, reference junctions for calibrating thermocouples, etc.

REPORTER

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Coating materials developed

Nichrome alloy, stainless steel, chromium, and modified molybdenum disilicide (LM-5)-type coatings can be used to protect columbium over the temperature range 900° to 1500°C. So reported S. T. Wlodek during the Third High-Temperature Inorganic Refractory Working Group Meeting held recently. Above 1150°C, LM-5 or LM-5 duplex coatings appear most promising as coating materials, he found. Type 302 stainless steel, Nichrome V, and chromium worked best below 1100°C, but chromium is limited in that such coatings allow oxygen contamination of the base metal to occur as low as 950°C.

* * *

Ceramic coatings can protect the high-temperature structural strength of tungsten at temperatures above 1650°C, a University of Illinois team reported during the recent annual meeting of the American Ceramic Society. C. G. Bergeron, V. J. Tennery, and A. L. Friedberg used a vitreous-type bonded refractory in which zircon was bonded with a high-temperature glass. The coating protected tungsten from oxidation for up to 10 hr when subjected to temperatures exceeding 1650°C.

Armco gaging hot strip

An infra-red width gage at Armco Steel Corp.'s Butler, Pa., strip mill is said to be cutting costs by eliminating waste and avoiding necked-down sections.

Called *Infra-Ray*, the gage is manufactured by Weston Instruments, div. of Daystrom Inc. The gage is non-contacting and operates from an infra-red sensing head mounted above the moving strip. The gage is said to be highly accurate and responsive at strip speeds up to 2000 fpm, and registers as long as edge heat is 900°F or more.

When steel is running, the head continuously transmits its measurement signals to console equipment for translation to visual indication at the finishing stand control station, speed pulpit, and roughing stands.

Add 0.2 pct boron 10 to steel

A new Type 304 stainless steel is said to have high neutron absorption and excellent mechanical properties when it contains up to 0.2 pct boron 10 isotope.

The new alloy, developed by The Carpenter Steel Co., is expected to find application in control rods and shielding for nuclear reactors.

Ordinarily, up to 2 pct natural boron has to be added to give a steel a sufficiently high thermal neutron absorption cross section. Adding this amount, however, sacrifices important engineering properties. But, by adding a much smaller amount of enriched boron—0.2 pct of boron 10 isotope—it is said to be possible to obtain mechanical properties and corrosion resistance almost as good as those in the basic alloy.

Bell growing gallium crystals

Production of single crystals of gallium phosphide by the floating zone melting technique is the goal of C. J. Frosch and M. Gershenzon, Bell Telephone Laboratories. They have, in fact, succeeded in growing single crystals about 3/4 in. long and 1/4 in. sq.

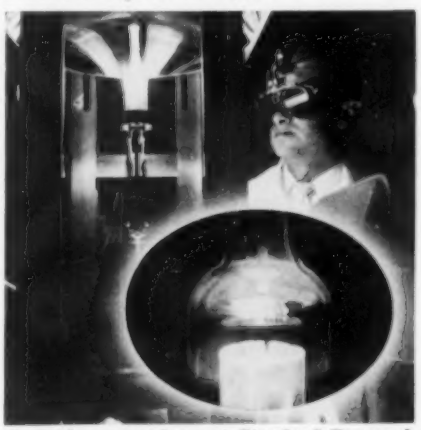
Since gallium phosphide decomposes at temperatures near its melting point unless held under high pressures of gaseous phosphorus, special equipment has had to be built. In the experimental equipment, an ingot of gallium phosphide is enclosed in a sealed quartz tube which is encased within a steel chamber equipped with viewing ports. At the temperatures and pressures involved (1450° to 1500°C and 10 to 50 atm pressure), the walls of the quartz tube fog over, making observation of the molten zone difficult. This can be overcome to a large extent by heating the walls of the apparatus to more than 950°C.

Bethlehem gets H-iron vessel

Delivery of a 285-ton pressure vessel to Bethlehem Steel Co.'s Los Angeles, Calif., plant is hastening the first US application of the H-Iron process to steelmaking. The H-Iron installation is scheduled for completion this year. The vessel, 6 ft x 6 in. in diam and 122½ ft long, is expected to convert pulverized iron ore into crude metallic iron pellets at the rate of 110 tpd. The pellets are to be used as charging material for the plant's electric-arc furnaces.

The unit will also include drying and grinding equipment for processing Venezuelan iron ore . . . a unit to manufacture hydrogen . . . and briquetting machinery.

Stanford crystal furnace



Ceramic researchers at Stanford Research Institute are growing high-purity single crystals of refractory compounds by a new technique. A dual-unit arc-image furnace is used to create a clean heat source and provide complete atmospheric control. The furnace consists of two arc units mounted face-to-face. They are separated by a 45° control that can be rotated to divert light from either unit to a vertical elliptical mirror. This, in turn, focuses the energy onto the growing crystal.

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letters to the editor

Point of Information

The following is a discussion of the article *Treatment of Copper-Nickel Matte*, by K. Sproule, G. A. Harcourt, and L. S. Renzoni, which appeared in the March issue, pp. 214-219.

The authors deserve recognition for the technological progress which they achieved in various branches of nickel metallurgy. However, as far as their matte beneficiation process is concerned, their report on prior art and their priority claim is subject to question. They overlooked a most important German publication on this subject (H. Schlect and L. Schlecht, *Erzmetall*, vol. IV, 1951, pp. 1-3) and their historical interpretation is misleading. The facts as they appear from the missing reference are as follows: H. and L. Schlecht of the I. G. Farben Industrie, A. G., on March 20, 1939 applied for a German patent which, according to the authors, covered the following steps of a Ni-Cu matte separation process: 1) Thermal treatment of bessemer Ni-Cu matte, for instance by controlled cooling of the sulfides as coming from the converter; 2) Comminution of the thermally-beneficiated matte; and 3) Mechanical separation of the powdered copper sulfide from the nickel-bearing powder, for instance by sieving, pulping, flotation, or by magnetic means. This appears to be substantially the process described by Sproule et al.

The Schlechts, in the reference cited, elaborate on how they came to this idea. In 1938 they found differential solubility in acids (US Patent 2,239,626 1941) between thermally-treated and untreated matte. They observed in the microscope that in the former case both compounds were cleanly separated and the crystals were considerably enlarged. They report as follows (translated): "From these observations we concluded that perhaps the large Cu_2S particles could be separated from the nickel-bearing particles by a mechanical treatment of the comminuted matte, such as sieving, flotation, and magnetic separation. Experiments performed in this direction showed that such mechanical separation can, in fact, be performed in a simple way." After this experimental confirmation, the Schlechts induced professor W. Koester and the Max Planck Institut to study the ternary equilibrium diagram very carefully to elucidate the thermal beneficiation effect. Professor Koester remarks in his publication (reference 13 of the Sproule article) that he found the conditions in the Ni-Cu-S system favorable for the separation. (See also Fiat Review of German Science. Part V. *Non Ferrous Metallurgy*, 1948, p. 255).

The patent to Stansfield et al (reference 12 of the article) does not recommend the heat treatment for the practical purpose of Ni-Cu separation. Nor has the Powell-Deering process (reference 8) of platinum elimination, after adding sodium sulfate, any relation to the Ni-Cu separation process suggested by the Schlechts.

It would appear, then, correct to state that the Koester publication of 1940 would give any skilled metallurgist enough suggestions and plenty of information for the technical development of the new matte separation process, even though the content of Schlechts' German patent application of March 20, 1939, might not have been open to the public until inspection of the Badische Anilin plant and of the German Patent Office files by Allied investigation teams, shortly after 1945, at the end of the war.

W. J. Kroll
Corvallis, Ore.

A Retort

We welcome the opportunity provided by Dr. Kroll's discussion to correct any possible misunderstanding in regard to the development at Copper Cliff of our process for the separation of copper sulfide from nickel sulfide in converter matte. He is obviously unaware of the facts, and others may also have been misled.

We did not review the 1951 article in *Erzmetal*, since we referred to the basic document involved—the Pauckner, H. Schlecht, L. Schlecht, and Hambrecht German patent application filed in 1939 but not open to inspection until 1951. This application demonstrates that their concept was mechanical separation of sulfur-deficient copper-nickel matte into two parts—both fractions high in copper and in nickel. The treatment was not designed to separate copper sulfide from nickel sulfide, but was aimed at separating a metallic nickel-copper fraction from a sulfide nickel-copper fraction. This concept actually prohibits separation of the bulk of the nickel from the copper.

The following provides additional information on early work in the above field. In 1892, D. H. Browne at Copper Cliff disclosed the separation of ferronickel crystals from a sulfur-deficient, copper-nickel-iron matte. As early as 1919, P. D. Merica at Inco's Bayonne Laboratory mechanically separated a metallic nickel-copper fraction from a sulfide nickel-copper fraction in heat-treated mattes. In 1925 Skappel disclosed a process of treating sulfur-deficient copper-nickel matte of high iron content to separate copper from nickel. In 1932, R. L. Peek at Copper Cliff attempted floating copper sulfide from nickel sulphide in converter matte, but the separation was poor. In 1940, Koster and Mulfinger studied the nickel-copper-sulfur system and stated that it was favorable for the separation of a pure nickel fraction from a copper-nickel sulfide fraction. However, even after optimum treatment, the metallics that can be separated from the usual copper-nickel mattes contain about 20 pct copper rather than the much lower copper content which they inferred.

Although the Schlechts have claimed anticipation of the Sproule-Harcourt process, it is significant that their German patent application was rejected on the ground that the examples and specification did not support the broad main claim, and that it lacked novelty. Useful separation of copper sulfide from nickel sulfide in matte was not obtained until as described in the 1943 Sproule-Harcourt patent applications, which have been allowed in the leading industrial countries of the free world, including Germany. The Sproule-Harcourt process provides copper sulfide low enough in nickel to be blown directly to blister copper . . . a nickel sulfide fraction low enough in copper for direct conversion to oxide for use by the steel industry . . . and a metallic fraction rich in precious metals. Dr. Kroll's closing comment regarding Allied investigation teams is irrelevant, since we had not only invented this process before V-E Day, but Inco had placed it in successful commercial operation.

W. K. Sproule
G. A. Harcourt

The International Nickel Co. of Canada, Ltd.

NOTICE TO AUTHORS

Make sure that manuscripts are typed double-spaced before submitting them to the JOURNAL OF METALS. Failure to do so results in retyping, chance of error, and needless delay. To facilitate matters, submit papers in duplicate and enclose illustrative material such as drawings and glossy photos at the same time. Such illustrations should be suitable for reproduction.

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editorial

Congratulations, Chiefs

Splendid cooperation, that's what we say with an expression of thanks to those more than 4000 members of The Metallurgical Society of AIME, who earlier this year took the trouble to fill out and return to the JOURNAL OF METALS' office an anonymous questionnaire giving information on educational background, present professional environment, age, and income during the year 1959.

Answers to questions on the form have been tabulated and analyzed by P. J. Clemm of GE and several of his associates . . . and they deserve quite a vote of thanks. We think that you will find the results interesting and helpful, and we would recommend your reading the 1959 Salary Survey appearing on p. 455 of this issue.

Before you leave this page though, we would like to point out that this is an example of what we can do for members of the metallurgical profession when we receive such excellent cooperation. We expect to continue keeping you abreast of the economic position of your profession on a periodic basis, in addition to providing you with all the information about developments in the metallurgical world.

And finally a compliment . . . we knew that we had a *top drawer* readership, but we didn't know how high *top* was. We're happy and pleased to announce what for us were the most exciting results of the Salary Survey. In the sample, 24 pct of you had Ph.D. degrees, 40 pct are engaged in the field of research, and 61 pct are managers or supervisors. So, we are really proud of our membership, and proud to be able to address such a professional group.

Thus, not only do we have thanks to say to you, but congratulations, chiefs!

FWS

TRANSACTIONS

OF THE METALLURGICAL SOCIETY OF AIME

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PERSONALS

(Continued from page 438)

Greenidge is now assistant coordination director at Battelle, while Mr. Nestor is manager of project development activities.

F. L. LaQue spoke on *Corrosion Through Pores in Protective Coatings* at a recent meeting of the American Society for Testing Material's Committee D-1. Mr. LaQue is vice president and manager of the Development and Research div., The International Nickel Co. Inc.

Albert De Sy, head of the metallurgy dept., Ghent University (Ghent, Belgium) was recently nominated to the Academy of Science (Royal Flemish Academy of Belgium) and was elected to honorary membership in the Société Francaise de Métallurgie.

Stanford O. Smith is now general manager of Mercer Alloy Corp., Greenville, Pa. Mr. Smith was formerly chief metallurgist at Texas Foundries Inc.

Reinhardt Schuhmann, Jr., professor of metallurgical engineering and head of the School of Metallurgical Engineering, Purdue University, recently gave a series of three lectures at the Imperial College of Science and Technology, Royal School of Mines (London). The titles of the April 26th and 27th lectures were: *The Role of the Engineering Sciences in Engineering Education . . . Metallurgy, Materials Sciences, and Engineering . . .* and *The Anatomy of Extractive Metallurgy.* Dr. Schuhmann is currently Chairman of The Metallurgical Society's Extractive Metallurgy Division.

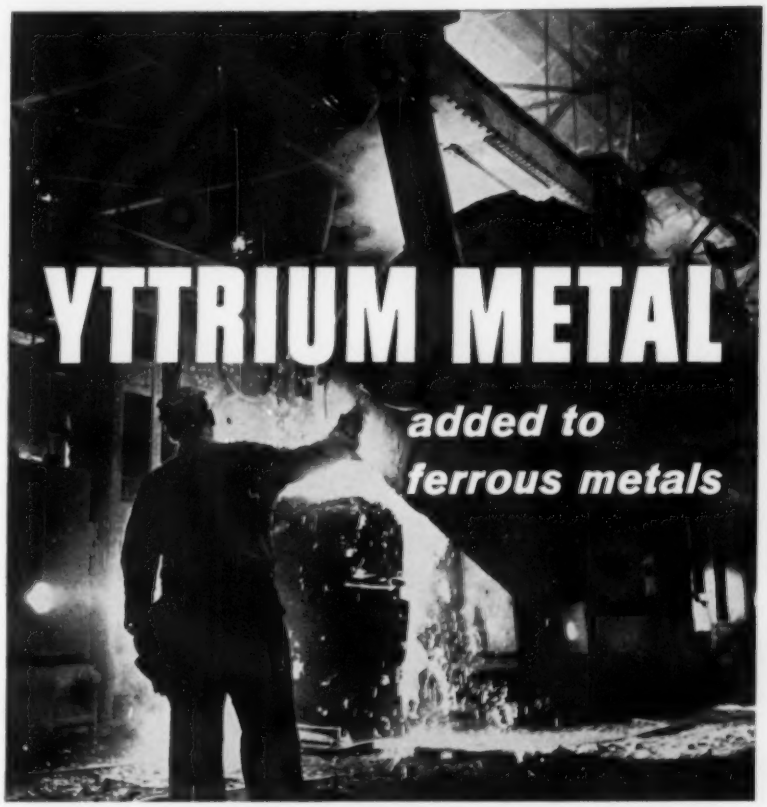
F. E. Werner has been appointed manager of the Alloy Studies section, Metallurgy dept., Westinghouse Electric Corp. Research Laboratories. Dr. Werner was formerly a research engineer at Westinghouse.

Heinz G. F. Wilsdorf has been promoted to a technical director of the Franklin Institute Laboratories. Dr. Wilsdorf will continue his former duties as head of the Laboratories' physics of metals branch, and now will also direct other branches—metallurgy, magnetics, and semiconductors.

S. L. Jackson has been appointed manager of the eastern sales region of Union Carbide Metals Co., div. of Union Carbide Corp. Mr. Jackson joined Union Carbide in 1942, and was assistant manager of the eastern region prior to the appointment.

George W. Healy is another Union Carbide Metals Co. appointee. Mr. Healy has been named senior research scientist for the Niagara Falls, N. Y., laboratory. In 1958 he

(Continued on page 446)



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PERSONALS

(Continued from page 445)

and D. C. Hilty, also of Union Carbide Metals, received the Robert W. Hunt Award for their paper, *Effect of Oxygen Input Rate in the Decarburization of Chromium Steel*. This Iron and Steel Division award winner was published in the May 1957 issue of JOURNAL OF METALS.

Harry Czyzewski, manager, Metallurgical Engineers Inc., Portland, Ore., has been elected president of the Consulting Engineers Association of Oregon for 1960-1961. Mr. Czyzewski, who is also National Director from Oregon to the Consulting Engineers Council, was chairman of the metallurgy program at the Pacific Northwest Regional Conference in April.

Kenneth A. DeLonge is now manager of direct sales for the Primary Nickel dept., The International Nickel Co. Inc. Mr. DeLonge, who joined International Nickel in 1937, was most recently sales manager for the Pittsburgh region.

Claus G. Goetzel has been retained as a consultant to Micro Metals Corp., conditioners and processors of iron and other metallic powders. Dr. Goetzel, an authority in powder metallurgy, is senior research scientist and adjunct professor in New York University's department of metallurgical engineering.

John L. Young and **J. D. Rollins** are among recent appointments announced by U. S. Steel Corp. Formerly vice president-appropriations, Mr. Young is now concerned with foreign and domestic engineering developments as vice president-engineering and research for the corporation. Mr. Rollins is now vice president-facility planning and appropriations.

L. Wallace Coffer has resigned from the Extractive Metallurgy Division's High Temperature Metals Committee in order to take a job in Australia. Formerly principal chemist in the Extractive Metallurgy div., Battelle Memorial Institute, Mr. Coffer is now director of the Australian Mineral Development Laboratories, Adelaide, S. Australia.

J. M. Crockett is now vice president-gases of the Air Reduction Sales Co. Inc. Formerly manager of Airco's Birmingham district office, Mr. Crockett will now be responsible for the production and distribution of the Co.'s complete line of industrial gases.

Walter J. Szymanski has become chief spectrochemist in the chemical Laboratory of Allegheny Ludlum Steel Corp.'s Watervliet works Previously, he was staff spectrochemist.

Eugene R. Dean has been promoted to assistant general superintendent in the Coke and Iron div., Pittsburgh Coke & Chemical Co. Mr. Dean had been superintendent of blast furnaces at the Co.'s Neville Island plant. Active in the AIME's Blast Furnace, Coke Oven, and Raw Materials Committee, he was Chairman of its Finance Committee in 1958.

Wallace M. Dillion, Jr. has joined the New York Trap Rock Corp. He was formerly with American Smelting & Refining Co.'s Chihuahua, Mexico lead smelter.

Russell Franks has retired from Union Carbide Metals Co., div of Union Carbide Corp., after more than 40 years of service with the Corp. An active AIME member for many years, Mr. Franks latest position was manager of the Marketing Research div. He holds more than 50 US patents on stainless and alloy steels.

Jerome B. Cohen is now asst. professor in the Department of Materials Science, Northwestern University. He recently completed a six months military obligation at the Ballistic Research Laboratories, Aberdeen Proving Grounds.

Metallurgists

Battelle has openings for several qualified metallurgists for research in the areas of:

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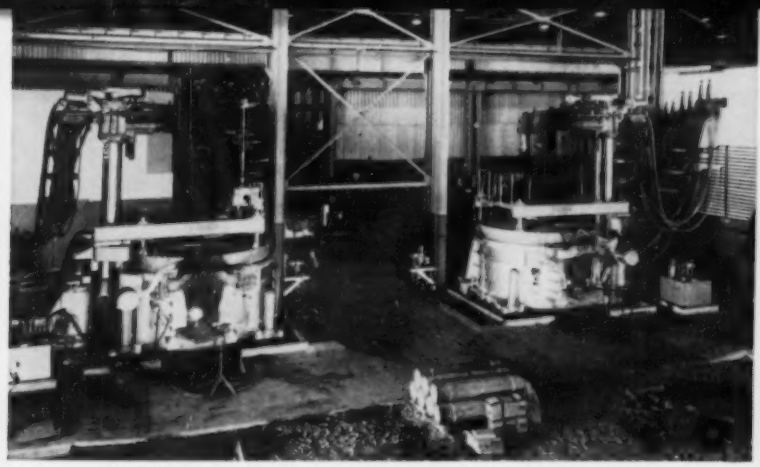
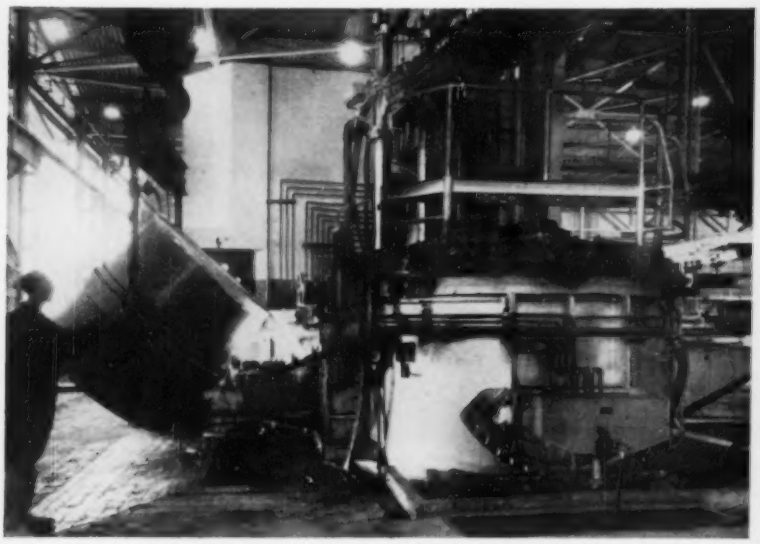
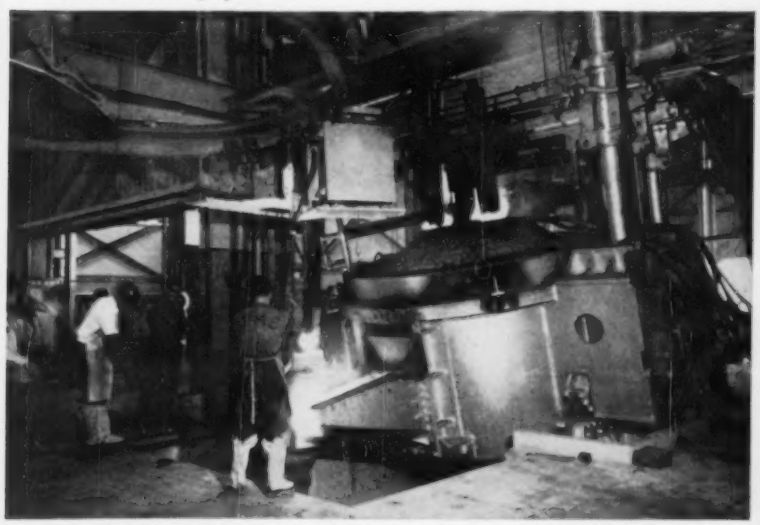


Two Lectromelt cold-melt batch furnaces melt gray iron.



Molten metal is transferred to Lectromelt duplexing furnace through special duck-bill receiving spout.



Duplexing furnace is tapped into ladles which are conveyed to pouring floor.

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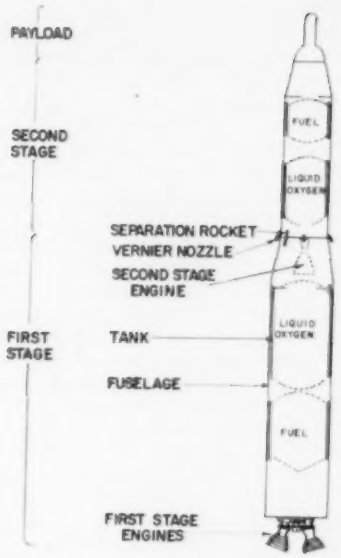
ROCKET MATERIALS
A Challenge for Metallurgists



"What is the role of metallurgy in the space age?" This article—written for those not closely associated with missiles—describes the major materials problems in rockets. A brief discussion of the environmental conditions, together with a review of the materials presently used, is given. Since many of the toughest problems are concerned with manufacturing methods, a short account of these is also presented.

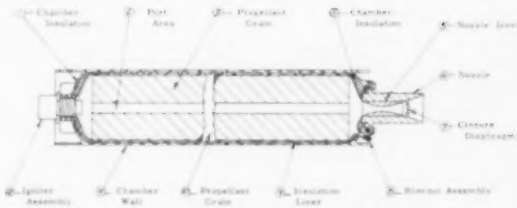


Fig. 1 (left)—Typical solid propellant rocket. Fig. 5 (above) — Two-stage liquid propellant rocket.

by E. S. Jones

A relatively new area of metallurgy and materials technology challenges the metals industry—that of selecting, developing, and applying the metals which make possible today's rockets. In a decade which will be highlighted by man's ventures into space, the role of rockets—large and small—is of tremendous importance to this Country. Rockets are also assuming an increasingly important position in our arsenal of weapons systems, ranging in size from the small *Sidewinder* air-to-air missile, to large ICBMs such as *Atlas* and *Titan*. But new rockets being developed for our space exploration program are of a size and power that will make the present generation of rockets seem small by comparison.

The rocket engines being developed to launch this wide variety of missiles and payloads are basically of two types: solid propellant and liquid propellant. The latter type has been under development in the US since the Army brought a nucleus of German scientists to this Country directly following World War II. Development of this type of rocket was continued in both the US and the USSR during the late 1940s, and with increasing emphasis in the past decade. The large engines developed in the past few years have primarily been of liquid propellant type for these reasons:

1) The high specific impulse available;
2) High over-all impulse:weight ratios achievable;
3) Relatively simple means of controlling the magnitude and direction of the thrust vector; and
4) Less severe materials problems.

E. S. JONES is with the General Electric Flight Propulsion Laboratory Department, Cincinnati, Ohio.

It appears that this type of rocket will have better performance than the solid propellant type for some years to come. However, advancement in the development of solid propellant rockets has been quite rapid in the past few years and the difference in performance has been narrowed. These advances have resulted from 1) steadily increasing specific impulse of solid propellants; 2) increased strength of the cases (lighter weight) and better nozzles (allowing longer and higher temperature burning); and 3) development of means for programming the thrust-time characteristics and controlling or reversing the thrust.

Much of the stimulus toward solid propellant rockets resulted from the need for ballistic missiles with instant retaliatory capability. In addition, the US Armed Services have long preferred solid fuels for anti-aircraft missiles or for ship-based rockets, since storage of liquid propellants presents hazardous problems.

Solid fuel rockets

A typical solid propellant rocket is shown in Fig. 1. The basic elements of this system are the cylindrical case containing the solid propellant fuel, an igniter assembly, a closure or cover, the exhaust nozzle, and (not illustrated) a means of thrust vector control by use of guide vanes, jetevators, vectorable nozzles, or other devices.

The two major material problem areas in this rocket type are 1) achieving the highest possible strength:weight ratio in the cylindrical case; and 2) successfully withstanding the ultra-high temperatures encountered in the nozzle and thrust vector control devices.

Considering high-strength case materials, it is well to review the environment encountered by the

case. The load is composed of longitudinal and hoop stresses resulting from the internal pressure produced by burning of the solid propellant . . . buckling stresses from the weight of upper stages (if a multi-stage type) . . . and from aerodynamic maneuvers. Developments in internal case insulation prevent the walls of first stage cases from being heated to any great extent by burning of the propellant—wall temperatures generally do not exceed about 250° to 300°F. Upper stages are likely to be somewhat hotter, since aerodynamic heating of the outer wall is likely to occur due to their high velocity in the upper atmosphere.

Since in all rockets one wants to achieve the lowest possible component weight in order to carry the maximum fuel or *payload* weight, it is obvious that the highest strength:weight ratio (consistent with buckling considerations) should be sought for the case. Fig. 2 contains a strength comparison of several actual and potential case materials. While yield strength and buckling characteristics* are the criteria most frequently used in comparing materials for design of cases, other factors such as cost and ease of manufacturing also are of importance. Although elastic behavior is usually assumed in the design of rocket cases, the ductility or strain capacity of the material is a paramount consideration. This is important since there are many regions of stress concentration resulting from fabrication, e.g., scratches, poor tolerances, etc., which can not be accurately predicted. Thus the material used for the case must be able to dissipate these concentrations by local yielding, without fracture. This quality is generally termed *notch toughness* and is a very essential characteristic of a successful case material.

Ordinarily, the cylindrical portion of the case is made by one of three methods: 1) roll forming a forged pre-form; 2) machining of ring forgings; and 3) the *roll and weld* method in which a sheet is rolled into a cylindrical shape and the edges joined by welding. The first method is preferred, since only circumferential welds are necessary, and the stress on these welds is only one-half that on longitudinal welds. Another advantage of the roll or shear forming method is that it is, in itself, an excellent quality control test, since any internal defects will be quickly revealed in the form of surface ruptures during the cold rolling.

Weld quality is an extremely important aspect of case design and manufacture, and it is regarded by many as a major barrier to development of higher strength cases. Defects (cracks or porosity), especially in longitudinal welds, are likely to result in serious consequences during pressurization of the case.

The domes or end closures for the cylinder are usually forged from billet slabs, and then machined to final dimensions. One end closure is then joined to the cylindrical portion of the case by a girth (circumferential) weld. The other end closure is mechanically attached, so that the case can be easily sealed after the solid propellant is cast into it.

The technology of high-strength steels has advanced to the point that cases of 150,000 to 200,000 psi yield strength level are not too difficult to achieve. Ductility and notch toughness (or resistance to crack initiation and propagation) of several low-alloy steels are reasonably good at this strength level, and the manufacture of high-quality, high-reliability cases presents only superficial difficulty.

The development of materials with yield strengths of 225,000 psi and above presents problems of a much greater magnitude. Failure of a trial case at this strength level has been reported[1] showing that the vessel literally disintegrated into dozens of fragments. This is a vivid illustration of lack of ductility and toughness that can result in steels at this high strength level. Many laboratories have development efforts in progress to identify alloy steels with a better combination of strength and ductility. Yield strengths of 275,000 psi and above, with attractive *uniaxial* ductility, have been demonstrated in a number of compositions. Less widely known, however, are the *biaxial* stress properties of such alloys. The rocket industry is giving increasing recognition to the importance of tests which simulate this load during the screening of candidate materials. Uniaxial strength and ductility values have been found to be totally inadequate in predicting case performance. As a result, such tests as notched tensile, bend, flat plate biaxial bulge, and small-scale pressurized cylinders are increasingly used for screening potential case materials.

Importance of cleanliness

A consideration of the relative merits of air vs vacuum-melted steels is appropriate at this point. The question is frequently raised as to which melting method should be specified for certain applications. These questions are usually prompted because of the price differential between air- and vacuum-melted material, which is about $1 per lb. Fig. 3 contains some recent data illustrating the difference in the notched-to-smooth tensile ratio between several air- and vacuum-melted steels. In nearly every instance, the notched-to-smooth ratio is higher for the vacuum than for the air-melted steel, indicating better biaxial ductility in the former. It is also interesting to note the difference in N:S ratio of AMS 6434 tempered to different strength levels. The higher the tempering temperature (lower strength), the less the difference in N:S ratio between air and vacuum-melted material. One should, of course, expect to see less difference at the lower strength levels.

The position being taken by more and more metallurgists and materials engineers is that the

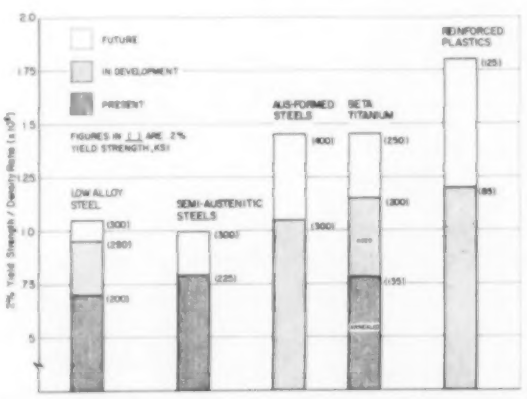


Fig. 2—Strength:density ratio for different case materials of solid propellant rockets.

* Buckling is a function of the modulus of elasticity, and section modulus of a material. It is only an important consideration while a case is not internally pressurized, such as occurs during firing. For example, an upper stage case is subjected to buckling loads while it is being accelerated during the firing period of the first stage booster.

choice between air or vacuum-melted material depends on the strength level to which a case is designed. If stresses are in the region of about 150,000 psi, it is probable that the inclusions, stringers, etc., in good-quality air-melted material will not promote crack initiation and propagation. Notch ductility and toughness at this strength level is sufficiently high that such internal *stress raisers* can be tolerated without difficulty. In the region of 200,000 psi yield, the situation becomes more critical. Notch ductility and toughness may still be good, but tolerance for surface or internal stress concentrations is lessened considerably, compared to the 150,000 psi strength level. It is a close decision as to whether air- or vacuum-melted material should be used in this instance. If quality control acceptance standards are sufficiently high, air-melted material may be successfully applied. If not, vacuum-melted material with better cleanliness would probably be preferred.

At strength levels in the region of 225,000 psi and above, the better cleanliness of vacuum-melted steels makes their selection almost imperative. At this strength level, stress concentrations resulting from inclusions or surface imperfections can have disastrous effects. Thorough inspection, utilizing the most advanced ultrasonic and X-ray techniques, is frequently used. These nondestructive inspection methods help increase reliability, and insure that all cases perform without malfunction.

Future outlook for cases

It appears that high-strength steels will continue to be the most widely used case materials. Strengths will be pushed upward while ductility and toughness adequate for design purposes will be maintained. It would appear that yield strength levels of 300,000 psi will be achieved in cases through heat treatment of alloys developed especially for this type of application. Even higher strengths can be achieved through warm working of certain steels

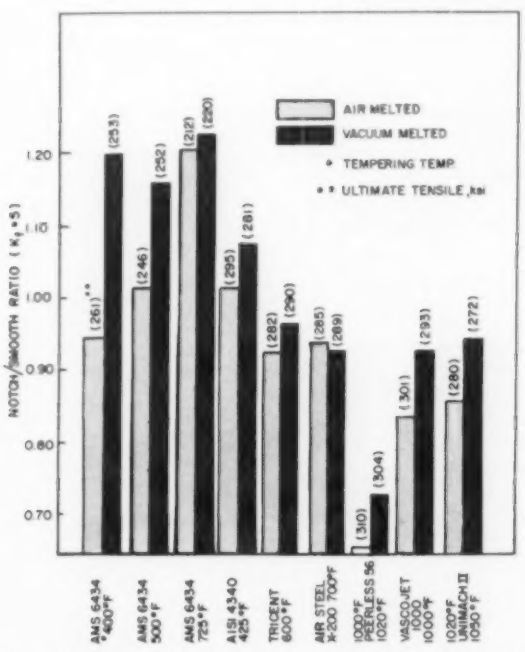


Fig. 3—Notch:smooth tensile strength ratios for several air- and vacuum-melted steels (by permission of General Aerojet Corp.)

in the metastable austenite temperature range (sometimes referred to as Ausforming). Rapid advances have been made in this area in the last few months.[5]

Of the *light* metals, titanium-base alloys are receiving widespread consideration. The relatively high cost (compared to steels) of this type of material tends to offset the strength:weight advantage that its use offers. The recently developed all-beta alloys can be processed to yield strength:density ratios of over 1,100,000—while maintaining significant ductility. Contrast this with the ratio of 900,000 for low-alloy steels with yield strengths of 250,000 psi. In rockets designed for moon exploration, each pound saved in *launch weight* means that many extra pounds of fuel can be available for use in returning to earth. Stated in other terms, each pound of payload weight saved in orbiting a satellite can amount to savings of hundreds or even thousands of dollars. Thus, there are specific types of cases where the slightly higher material cost of titanium will be more than compensated for by allowing larger payloads.

Perhaps the ultimate in strength:weight ratio will be achieved when plastics can be routinely applied to cases. As shown in Fig. 2, plastics greatly exceed metals in strength:weight ratio. Present limitations include temperature capability and low modulus. Continuing developments in this area may well put the chemists to the forefront as case material experts.

Nozzles and thrust vector controls

The second major materials problem area in solid-propellant rockets is that of the nozzle and thrust vector controls. Fig. 1 shows a schematic view of a typical nozzle system. The requirements of these components are 1) lightness in weight; 2) resistance to ultra-high temperatures and high heat fluxes; and 3) thermal shock and erosion resistance.

In principle, the nozzle provides a means of controlled expansion of the gases generated by the burning propellant, this in turn controlling the thrust of the engine. The nozzle must be highly stable dimensionally in order that the throat, or orifice, does not become enlarged by erosion or melting. Should the throat area become larger during firing, chamber pressure would drop correspondingly—resulting in unstable thrust characteristics and an unpredictable flight trajectory.

Present solid propellants burn at temperatures of 4000° to 6000°F; burning times may vary from a few seconds to perhaps 2 min. Compared to those experienced in land gas turbines or jet engines, the temperatures, pressures, and heat fluxes encountered in the nozzles of rocket engines indeed present a challenge to the resourcefulness of metallurgists and design engineers.

Control of the thrust direction (for guidance) is achieved by either of two means. One consists of *gimbaling* or *swiveling* the nozzle so that the direction of the exhaust gases (and hence thrust) can be altered for guidance purposes. Gimbaled nozzles pose the problems of a high-temperature bearing at the support areas, and leak-proof seals. The nozzle actuators and structural arrangement are also fairly complicated.

The second device involves the use of external *jetevators* or jet vanes in the exhaust gases (Fig. 4). These vanes are merely control surfaces which deflect exhaust gases at varying angles, with re-

sultant changes in the thrust direction. Extremely severe thermal gradients and highly oxidizing conditions characterize the environment of these components. In the case of jet vanes, four of them are needed for complete flight control (pitch, yaw, and roll). The jetevator ring has an advantage in that it is exposed to the exhaust gases only when it is actually performing its required function. It is, therefore, subjected to less time in the exhaust gases and erodes more slowly than jet vanes, which are continuously exposed to the exhaust.

To further complicate the conditions in which nozzles and jetevators must function, the effects of fuel additives must be considered. Certain metallic additions, such as powdered aluminum, are sometimes made—increasing the propellant burning temperature and hence its performance. By so doing, however, the erosive characteristics of the exhaust gases are greatly increased, and deposits of additive metal oxides tend to adhere and accumulate on cooler regions of the nozzle and control surfaces. Erosion or deposit build-up accelerates deterioration and decreases the reliability of the nozzle system.

Nozzle materials

From the previous discussion of nozzle operating conditions, it should be evident that very few, if any, *off the shelf* materials can successfully satisfy all requirements. Indeed, adequate nozzle materials are probably one of the main limitations to the continued performance improvement in solid fuel rockets.

The refractory metals, tungsten, tantalum, and molybdenum, are the only metallic materials having melting points high enough to be considered for most nozzles. They also have good resistance to thermal shock and erosion. Disadvantages include high density and high transition temperature (especially tungsten and molybdenum). While the oxidation resistance of these metals is poor, this is usually not a problem since the exhaust gases are neutral or reducing, and exposure times at high temperatures are short, being measured in seconds or minutes rather than hours.

While tungsten, tantalum, and molybdenum offer some attractive properties, weight considerations generally preclude the use of nozzles made entirely from these high-density metals. Instead, the design usually incorporates thin *liner* inserts of these metals in the region of maximum heat flux, backed up by lighter weight, thermally-insulating materials.

Each of these metals, and alloys thereof, have been tested or actually used in nozzles, jetevators and vanes. Depending on the type of fuel and duration of firing, different performance characteristics have been obtained. In general, tungsten has demonstrated the best characteristics to date. Having a melting point of 6170°F, (3410°C) it would be expected to possess the best resistance to melting. However, thermal conductivity . . . the type of back-up material . . . and the intensity of heat flux are also important variables which influence performance.

Nozzle inserts of refractory metals can be made by several methods. All can be prepared as billets by powder metallurgy or arc melting techniques, then hot forged to oversize preforms. These forgings are then machined to final dimensional tolerances. Another method consists of depositing tungsten, tantalum, or molybdenum on a mandrel of brass, steel, or plastic by metallizing, plasma arc spraying, and other similar techniques. In these processes, the metal to be deposited is melted by an electric arc, and then the molten metal particles are propelled to the surface to be coated by a rapidly moving flow of appropriate inert gases. After depositing the metal to the desired thickness, the mandrel form is removed (by chemically dissolving, melting, or by a detachable joint), and the resulting refractory metal *shell* is sintered at high temperatures for increased density.

Other methods of insert manufacture being studied include slip casting, sintering, roll forming, and spinning. Of the processes described, those which result in a wrought microstructure have demonstrated the best ductility and resistance to thermal shock.

Graphite

Graphite is being tested extensively for nozzles, and as a backing for deposits of refractory metals. Being quite light and resistant to thermal shock (used for years as electrodes in electric furnaces), it is naturally a material having widespread interest to nozzle designers. A further advantage is that components can be easily machined from solid blocks of graphite which are relatively cheap and easy to obtain.

There have been somewhat conflicting reports from different groups concerning the performance of graphite nozzles. This is probably due in some instances to non-uniformity in the quality or grade of graphite being used.

While graphite has many advantages, it also suffers from certain property deficiencies. Erosion resistance is one of its weak points; poor oxidation resistance is another. Both of these undesirable properties contribute to dimensional instability in nozzles, especially if the propellant contains metallic additives, or the combustion products are slightly oxidizing.

Recently much interest has been focused on the properties of pyrolytic graphite. This is essentially an oriented, crystalline, high-density form of graphite which is deposited by high temperature decomposition of certain hydrocarbon gases. In the plane parallel to its surface, the thermal conductivity is higher than copper, while conductivity normal to the surface is lower than regular graphite. This directional characteristic, of course, adds to its attractiveness as an insulator. The density of

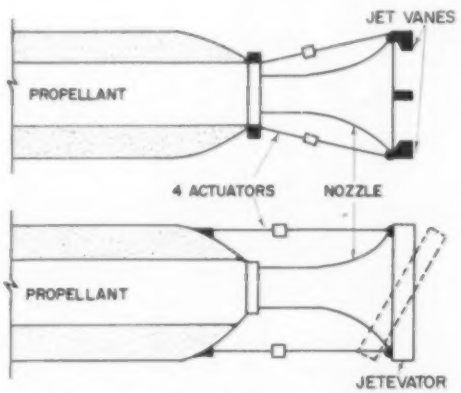


Fig. 4—Schematic view of jetevators and jet vanes used to control thrust direction.

regular graphite is 1.6 to 1.7 g per cu cm, compared to densities of over 2.1 for pyrolytic graphite (theoretical density is 2.26). Density increases with temperature of deposition due to a greater preferred orientation at higher temperatures. This increased density contributes to higher strength and lessened notch sensitivity. Strengths as high as 50,000 psi at a temperature of 5,000°F have recently been reported—about an order of magnitude higher than conventional graphite.

High-temperature tests have shown that pyrolytic graphite has much better erosion resistance than the high-grade molded or extruded graphites. This improvement in erosion resistance is attributed to the oriented crystal lattice which presents relatively high strength basal planes to the gas stream.

Ceramics and insulation materials

Nozzle inserts of various carbides, oxides, borides, and nitrides have been evaluated. While initially encouraging results have sometimes been shown in tests on miniature nozzles, scaling up to larger sizes (increased section thickness) has often met with failure from thermal shock. Melting point considerations also limit the known compounds which can withstand the temperatures associated with the newer, high-performance propellants. This, coupled with generally poor thermal shock resistance, serves to make these materials less attractive than those previously described for high performance nozzles.

Conversely, certain ceramics used as thin coatings on graphite, steel, or refractory metals have been tested with some success. Oxide ceramics such as ZrO_2 and Al_2O_3 appear to have attractive properties if properly applied, and if time and temperature conditions of service are not excessive.

Insulation from extremely high temperatures is required in the convergent portion of the nozzle, and also in the casing and the closure containing the blast tubes to which the nozzles are attached. This insulation must not only serve as a heat barrier, but must also resist the severe erosion resulting from high-velocity, high-pressure gases from the burning propellant. It must also be sufficiently ductile to accommodate 1 to 2 pct dilation (expansion) of the nozzle or case material. The usefulness of insulation materials is often measured by determining the time required to reach a certain temperature on the *cold* side when a high heat flux is applied to the *hot* side. Other tests permit relative measurement of erosion and ablation. Mechanical properties, and ability to bond to the propellant and chamber, must also be carefully evaluated.

Phenolic and epoxy laminates, asbestos mat or felt impregnated with phenolic resin, asbestos-rubber compounds, and vitreous ceramic fibers have proven to be effective insulating materials, having both good erosion resistance and insulating properties. However, there is a very real need for development of insulation with lower thermal conductivity, so that thinner layers may be used with resultant weight saving.

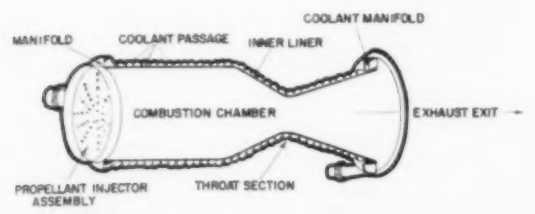


Fig. 6—Regenerative cooling of nozzle in liquid propellant rocket.

Liquid propellant rockets

The basic elements of a liquid-propellant rocket are shown in Fig. 5, p. 449. Propellants (commonly liquid oxygen and a hydrocarbon fuel) are ducted from storage tanks forward of the nozzle area to a fuel injector which atomizes the propellant mixture prior to burning. Turbo pumps, aided by pressurization of the tanks, bring the *LOX* and fuel to the nozzle area. Burning is usually initiated by an electrical ignition system, and the combustion products are expanded through converging–diverging nozzles. The nozzle walls are cooled by pumping the fuel through tubular passageways encircling the nozzle shell.

In contrast to the solid propellant rocket, the liquid propellant rocket is usually fueled a short time before being launched. In early stages of development, it was common for the fueling and *countdown* operations to extend over a considerable time period, sometimes lasting several hours. The complexity of this type of fueling operation, plus the desire for instant launching capability, provided the stimulus for the development of the solid-fuel types. The simplicity of storing a solid propellant has many obvious advantages. However, operational advantages of the solid propellant type are certainly accompanied by a host of materials problems. The prospects are encouraging for developing storable liquid propellants with the readiness capabilities of solid propellants, together with the high specific impulse of liquid propellants.

The materials used in the construction of liquid-fuel rockets differ markedly from those required in the solid-fuel type and the material problems in the liquid fuel type are not nearly as severe or as challenging. As previously discussed, regenerative fuel cooling is used to keep the nozzle walls reasonably cool. There is no requirement for ultra-high strength casings, since they are not subjected to the high internal pressures that characterize the solid propellant type. While the material environmental conditions are not as severe as in the solid fuel type, the fabrication and quality requirements present quite difficult obstacles.

Fuselage and tanks

In the *Atlas* missile, the primary structural material is Type 301 stainless steel. Thickness tolerances on the sheet are extremely tight, since weight is of such vast importance. The major metallurgical areas of interest are those of the forming and joining operations. Certain successfully stretch-formed parts would defy fabrication by more conventional techniques. Fusion welding is done by the helium-shielded, inert-arc process, so that a minimum of atmospheric contamination occurs in the weld. A grooved *back-up* bar enables a stream of helium to protect the back side of the weld joint from atmospheric contamination. A much more detailed description of the fabrication techniques used in manufacturing the Atlas has been recently published.[8]

In the *Titan* missile, 2014-T6 aluminum alloy is used for the first stage fuselage, including extruded sections with integral stiffeners for structural

strength. Chemical milling is employed to reduce section thickness in areas not highly stressed. The second stage is also made from 2014-T6 Al alloy sheet. Heliarc welding is used for most of the joining operations, since this process results in a minimum heat-affected zone. Magnesium alloys, in sheet, extrusion, and cast forms, are being successfully used in missiles such as the *Bomarc*, *Falcon*, *Regulus*, and *Titan*.

The use of liquid oxygen (−362°F) and, more recently, liquid hydrogen represents a materials problem of some magnitude. Tanks and ducting for liquid oxygen are usually made from stainless steel, aluminum, or *K* Monel, and no particular difficulty is encountered. Liquid hydrogen (−423°F) presents a far greater problem. At this temperature, many alloys (mostly bcc types) behave in a very brittle manner. The literature indicates that, in general, fcc materials possess good strength and ductility at low temperatures. Table I contains tensile data on a number of materials that have been investigated for possible use in handling cryogenic liquids. Fortunately, several of the austenitic stainless steels retain excellent ductility and can be successfully used for handling liquid hydrogen if proper hardware design and fabrication procedures are followed. It is interesting to note that one of the most severe thermal gradients the rocket metallurgist is likely to encounter occurs in a nozzle shell which contains liquid hydrogen on one side and +6000°F exhaust gases on the other.

Ducting and fuel injectors

Some of the foremost hardware problems are those concerned with the tubing, ducting, pumps, etc., for handling of the propellant. High pressures —often as high as 500 psi—are required to rapidly force large quantities of propellant to the nozzle. When one considers the problem of leaks, faulty valves, corrosion, and plugging that can occur in a low pressure (approx 50 psi) home water system, it is easier to appreciate the difficulties associated with handling cryogenic liquids, and sometimes very corrosive oxidants, at such greatly increased pressures.

Certain rockets use acids such as fuming nitric acid as the fuel oxidant. The corrosion problems involved with handling acids are quite evident. Not so obvious, though, is the situation that exists when an engine is test fired on the ground, prior to actual flight firing. The fuel and oxidizer are pumped through the fuel lines, pump, and injector. After a short firing cycle, the test is terminated. However, the acid remains in the lines, pumps, and valves —necessitating the thorough flushing of all fittings to prevent severe corrosion. Thus, long delays that are sometimes encountered in the course of countdown operations give rise to a great many secondary problems.

The fuel injector is one of the most critical in a liquid fuel engine. Its function is to mix and atomize effectively both components of a bi-propellant system so that properly controlled combustion can take place. Bronze, steel, or aluminum is usually used for this intricately-machined part, for experience has shown that these are the materials having the needed combination of erosion resistance, high thermal conductivity, and machinability. During firing, the fuel spray ignites a short distance from the surface of the injector, and since it is cooled by liquid fuels, it remains at a reasonably low temperature. The design of the injectors has gradually evolved through test experience. The combination of propellant spray angles, mixing characteristics, and spray length—which produce the best combustion pattern, and yet prevent overheating of the injector face—have been the result of years of study and testing.

Table I. Properties of Several Materials at Liquid H_2 Temperature (−423°F)*

Material	U.T.S.	0.2 % Y.S.	% El.	0.2 YS/Density Ratio (x 10^6)
Type 302 SS	257,000	62,000	40	2.2
Type 316 SS	225,000	97,000	50	3.3
Beryllium Copper	218,000	190,000	9	6.3
A110 Titanium	240,000	228,000	13	14.2
6061 Al	56,000	15,000	30	1.5
R-41 (Ni Base)	265,000	200,000	15	6.7

* General Electric Co., unpublished data.

Nozzles

As shown in Fig. 6, the nozzle consists of a shell of low alloy or stainless steel, surrounded by passageways or ducting for the propellant. This ducting is often copper, since high thermal conductivity is so important. Heat transfer characteristics must be such that the circulation of the propellant over the outer wall of the nozzle shell keeps the inside wall at a reasonably low temperature, so that melting of the nozzle wall does not occur. A very critical relationship exists between hoop stress, hydraulic pressure, heat transfer, propellant stability, and many other factors that influence the design of liquid propellant nozzles.

There are a number of variations of the regenerative cooling concept, especially in methods of ducting the propellant. These can consist of brazed tube bundles, spiral baffles between an inner and outer shell, and other similar modifications.

Summary

The rockets in general use today may be divided into two types, those utilizing 1) solid propellants and 2) liquid propellants.

From the standpoint of the metallurgist, the solid rocket presents materials problems of the greater magnitude. High strength: weight ratio materials for the cases, and ultra-high temperature resistant materials for the nozzle area are perhaps the most challenging problems. Materials advancements in both of these areas will allow higher performance to be realized.

The liquid propellant rocket has less severe material requirements, but is more complex mechanically. High metal temperatures are avoided by the use of regenerative cooling, i.e., circulation of the propellant over metal surfaces to extract heat. Handling of cryogenic liquids, high-pressure ducting, corrosive mixtures, and bi-propellant mixing are typical of the problems associated with liquid propellant rockets.

References

[1] Shank, Spaeth, Cooke, and Coyne: Solid-Fuel Rocket Chambers for Operation at 240,000 psi and Above, *Metal Progress*, Nov. 1959, p. 77.

[2] *Defense Metals Information Center Report*, No. 39, Nov. 30, 1959.

[3] A. Hurlich: Metals and Fabrication Methods Used for the Atlas, *Metals Progress*, Nov. 1959, p. 65.

1959 SALARY SURVEY of THE METALLURGICAL SOCIETY

An analysis of the recently completed income survey of The Metallurgical Society, conducted by a subcommittee of the Committee on the Metallurgical Profession.

Members of the Salary Survey Subcommittee are:
F. W. Starratt, Journal of Metals,
P. J. Clemm, General Electric Research Laboratory,
S. G. Fletcher, Latrobe Steel Co., and
W. R. Opie, National Lead Co.
Analysis of the data and preparation of this report was carried out under the direction of P. J. Clemm.

Earlier this year all members of The Metallurgical Society of AIME residing in the United States were asked to fill out a questionnaire relating to their educational background, present professional environment, age, and income during the year 1959.

This survey is the second one conducted by The Metallurgical Society. The first one took place a year earlier and the results were published in the JOURNAL OF METALS in June 1959. The 1958 survey provided a most valuable background for the design of the present survey in that the returns indicated which question areas did not provide sufficiently large samples for the construction of median salary curves or other statistical analysis. It was possible, then, to avoid these particular areas and to include some new questions instead. Most of these new questions were aimed at trying to discover correlations between an individual's educational background and his subsequent professional success measured in terms of financial income. Such correlations were indeed found, although this does not, of course, necessarily imply a cause and effect relationship between the correlated factors.

For example, there is a significant statistical correlation between the size of a school (in terms of numbers of students) where a person received his degree and his subsequent financial rewards. Interestingly enough, this relationship is opposite for the bachelor and doctoral degrees—the largest schools graduate the highest-paid B.S.'s; the smaller schools the highest-paid Ph.D.'s Now it would certainly appear unreasonable to cite size *per se* as a causal factor: the cause must be sought rather in some third factor or combination of factors which happens also to correlate with size. The primary purpose of this article is merely to present the statistical facts and let the reader draw his own conclusions; it does not attempt to elucidate such causal factors.

Mechanics and procedures

Of 7500 questionnaires mailed to members of The Metallurgical Society residing in the US, slightly more than 4000 were filled out and returned. Some could not be used because they were returned too late to be included. Others were held invalid for the purposes of this analysis because of insufficient information relating to age or income. Other returns were excluded from the analysis as special cases, namely those from students, members of the Armed Forces, retired members, and non-retired members over 65, of whom there was an insufficient number to provide a statistical sample. This left a sample population of 3598 returns, all from non-retired, non-student, and non-military members between the ages of 20 and 65.

The information from the questionnaires was punched on IBM cards, machine-sorted according to age and salary, and the number of returns in each salary bracket tabulated by groups corresponding to the several possible answers to each question. From these tabulations, median salaries and, in some cases, the upper and lower decile salaries were computed. In order to reduce scatter, each point was computed on the basis of a five-year age group symmetrical about that point. Since income was given only to the nearest whole thousand dollars, a linear distribution in each thousand dollar

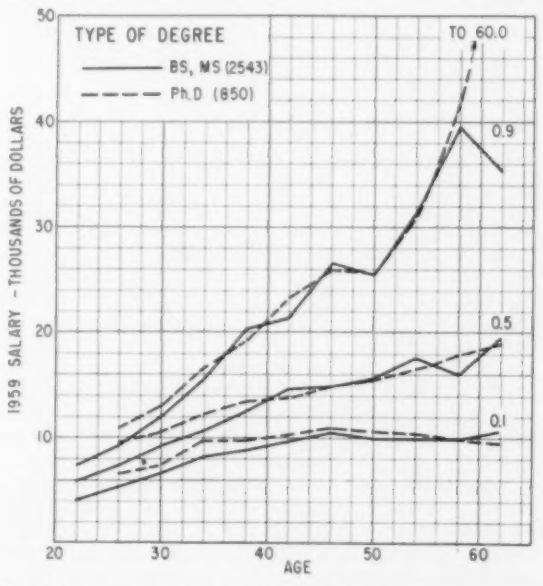


Fig. 1. Median, upper decile, and lower decile salary curves by type of degree.

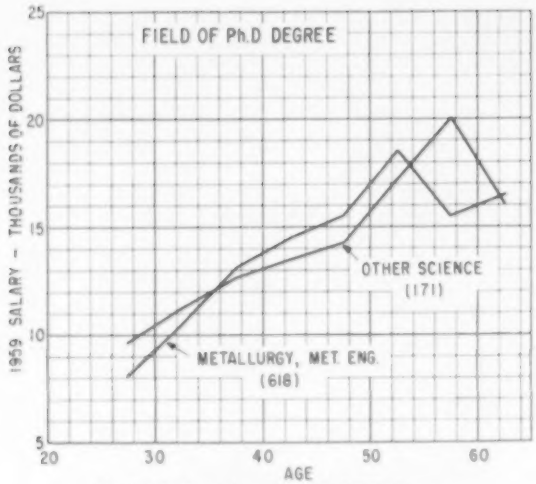


Fig. 2. Median salary by field of PhD degree.

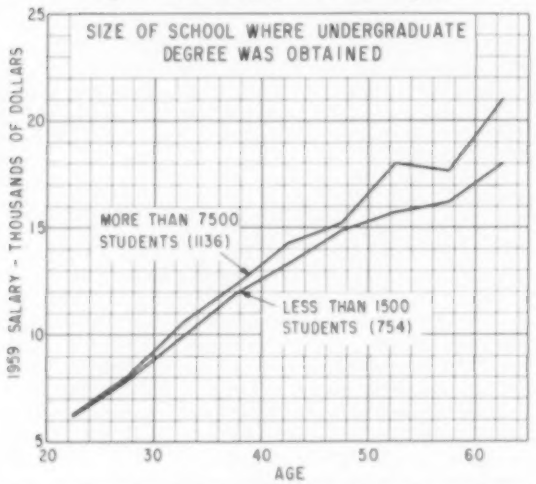

SIZE OF SCHOOL WHERE UNDERGRADUATE DEGREE WAS OBTAINED
1959 SALARY - THOUSANDS OF DOLLARS
AGE
MORE THAN 7500 STUDENTS (1136)
LESS THAN 1500 STUDENTS (754)

Fig. 3. Median salary by size of school where BS degree was obtained.

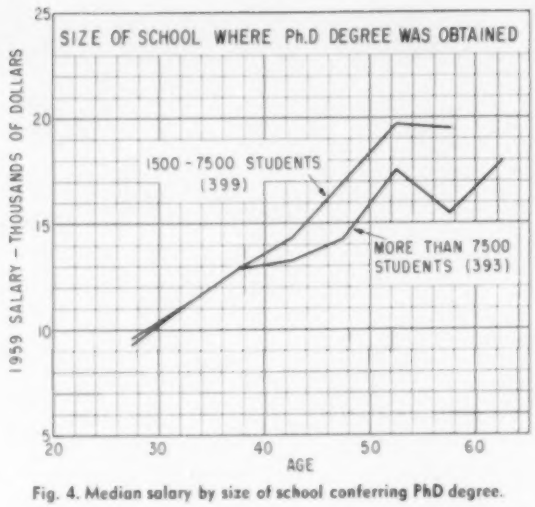

SIZE OF SCHOOL WHERE Ph.D DEGREE WAS OBTAINED
1959 SALARY - THOUSANDS OF DOLLARS
AGE
1500 - 7500 STUDENTS (399)
MORE THAN 7500 STUDENTS (393)

Fig. 4. Median salary by size of school conferring PhD degree.

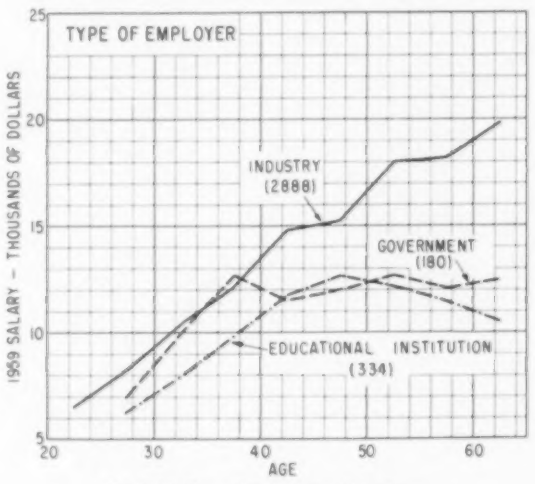


Fig. 5. Median salary by type of employer.

range was assumed. Using this assumption, all points falling within a thousand dollar range were plotted on a linear interpolation to the nearest one hundred dollars.

Results of the analysis

The results presented here consist of the median salary curves for various groupings shown in Table I. This tabulation also gives the total number of returns in each grouping, the percentage of the whole population in a particular group, and the percentage of the population under 40 years of age in a particular group. A comparison of these latter percentages shows some interesting differences. Such a comparison of the relative distribution within the younger professional population of The Metallurgical Society as compared with the whole Society may provide some clues to long-term shifts and trends in the metallurgical profession as a whole.

Comparing the 1959 results with the 1958 survey shows the median salary curve for the whole population to lie about 6 pct higher initially and gradually to fall back into the 1958 median curve around age 35. This would appear to suggest that inflationary increases have taken place primarily in starting salaries and in the salaries of the younger age groups. However, the point scatter of the curves is such as to prevent a precise estimate of inflation from the data. In each of the following figures, the numbers in parentheses indicate the number of returns in a particular category.

Type of Degree

Fig. 1 shows upper decile, median, and lower decile salary curves for two groups: those whose highest degree is a bachelor's or master's degree, and those who have a Ph.D.

As was found in the 1958 survey, there is no significant difference between those with a bachelor's and those with a master's degree. The difference between the incomes of Ph.D.s and non-Ph.D.s appears to exist primarily in the lower age group and to persist longer in the lower decile than in the median and upper decile. This may be due to the fact that the majority of those in the median and upper decile group are managers and supervisors whose incomes are not as strongly influenced by academic degree.

Field of Degree

Salaries do not appear to be significantly affected by type of B.S. degree. The only noteworthy fact here is that a significantly greater proportion of the Society members under 40 hold B.S. degrees in

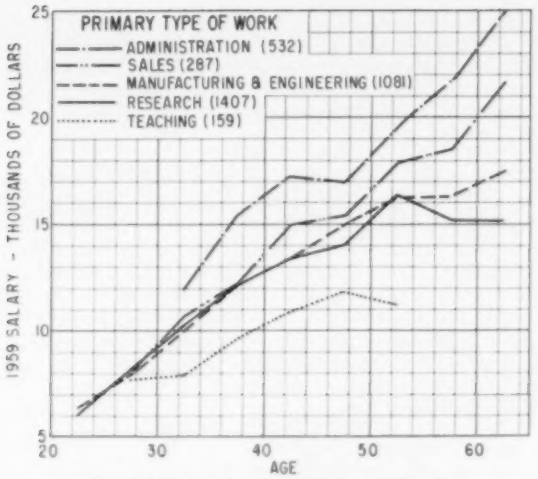


Fig. 6. Median salary by primary type of work.

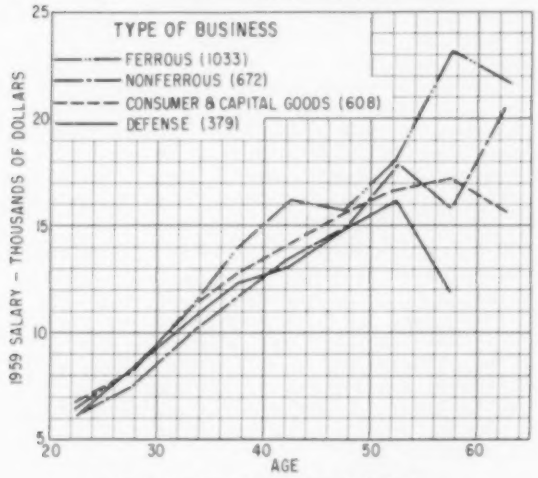


Fig. 7. Median salary by type of business.

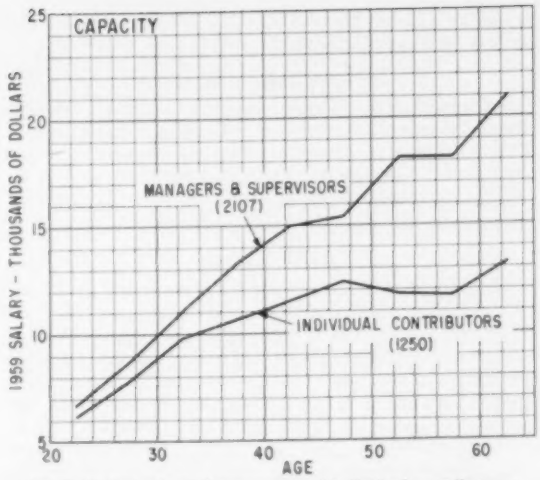


Fig. 8. Median salary of managers and individual contributors.

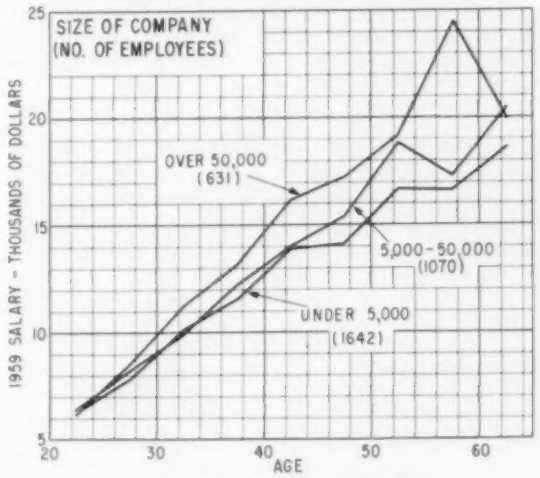


Fig. 9. Median salary by size of company.

metallurgy or metallurgical engineering than is the case for the Society as a whole (70 pct as against 58 pct). This is, undoubtedly, a reflection of the faster growth of metallurgy departments in our schools in recent years relative to other science and engineering departments.

The field of a Ph.D. does not correlate very consistently with median salaries, as may be seen in Fig. 2. *Other Engineering* and non-technical Ph.D.s were not sufficiently numerous to allow calculation of a median line. The trend towards a greater proportion of metallurgy Ph.D.'s in the under 40 age group was also evident, although not as strongly as with the B.S.'s (See Table I).

Type and Size of School

No correlation between type of school and median salaries could be determined. A somewhat larger than average proportion of the *under 40* Ph.D.s were found to have done their graduate work at technological schools as distinct from universities; however, the majority were still university Ph.D.s.

The correlation observed here, which has already been referred to, is one of the more surprising facts to have emerged from this survey. Fig. 3 shows the median salary curves for B.S. degrees from the largest and smallest schools. While the actual difference in median salary is small over most of the age range, the fact that this difference is in the same direction for every five-year age group does give it statistical significance. Furthermore, the curve (not shown) for the intermediate size schools (1500 to 7500 students), while it crosses the other curves at a few points, lies for most of its length intermediately between the other two.

The difference between the Ph.D. curves (Fig. 4), while existing only above age 40, is quite pronounced. In considering this phenomenon, one may be tempted to conjecture that during the last 15 to 20 years the quality of graduate instruction in the larger schools has improved relative to that in the smaller schools. As noted earlier, however, such speculations involving cause and effect relationships would need much further substantiation before they could be accepted as valid conclusions.

Type of Employer

The curves in Fig. 5 bear out the usually-accepted dictum that industry pays higher salaries than do educational institutions or the government. Borne in mind, however, should be the fact that 44 pct of the returns from educational institutions reported *other professional income* whose median value (average over-all age groups) amounted to $3,100 per year. In other words, the median for *total* professional income for the educators would

lie about $1,500 higher, on the average, than the median income from salary alone.

Primary Type of Work

In these curves (Fig. 6) wide differences are apparent between the various functions. Those in administration are, almost without exception, also managers. It is interesting to note that 40 pct of our sample population is engaged in research, increasing to 49 pct for those under 40.

Type of Business

Here, in Fig. 7, the differences are not so great; however, the steel industry stands out as the pace setter. In this breakdown, the only notable variation in the percentage of the whole population as compared to the under 40 group is that of the nonferrous industry: their proportionate share of the under 40 group is one-third smaller than their share of the total. Another, perhaps surprising feature, is the defense industry curve: one frequently hears of the high salaries paid in defense work; evidently this does not hold true for metallurgists. The consumer and capital goods industries have been plotted on one curve since their median points fell quite close together.

Capacity

The difference between the salaries of managers and supervisors and those of individual contributors (shown in Fig. 8) is a fairly substantial one. Another important point to bear in mind here is the fact that fully 61 pct of our sample population are managers or supervisors. This imbalance in our population will receive further attention later.

Table I. Tabulation of 1959 Salary Survey Returns

Factor	Groups	No. of Returns in Each Group	Pct of Whole Population	Pct of Under 40 Population
Highest Degree:	None	205	6	2
	BS	1554	43	42
	MS	989	27	26
	PhD	850	24	30
Field of BS:	Metallurgy, Metallurgical Eng.	2004	58	70
	Other Engineering	637	24	17
	Other Science	500	16	12
	Non-Technical	85	2	2
Field of PhD:	Metallurgy, Metallurgical Eng.	618	73	79
	Other Engineering	53	6	5
	Other Science	171	20	15
	Non-Technical	8	1	1
Type of School: (BS)	Liberal Arts College	278	8	6
	Technological School	1234	36	37
	University	1952	56	57
Type of School: (PhD)	Liberal Arts College	11	1	1
	Technology School	290	34	38
	University	553	65	61
Size of School: (BS)	Under 1500 Students	754	22	17
	1500-7500 Students	1577	45	45
	Over 7500 Students	1136	33	38
Size of School: (PhD)	Under 1500 Students	55	7	5
	1500-7500 Students	390	47	48
	Over 7500 Students	393	46	47
Type of Employer:	Industry	2888	81	79
	Government	180	5	5
	Educational Institution	334	10	11
	Independent Research Institute	149	4	5
Type of Work:	Research	1407	40	49
	Manufacturing & Engineering	1081	30	31
	Administration	532	15	6
	Sales	287	8	7
	Teaching	159	4	4
	Other	96	3	3
Type of Business:	Ferrous	1033	31	29
	Non-Ferrous-Production	672	20	13
	Consumer Goods	196	6	7
	Capital Goods	412	12	13
	Defense Products	379	11	15
	Other	671	20	23
Capacity:	Individual Contributor	1250	37	53
	Manager or Supervisor	2107	61	46
	Self-employed Consultant	35	1	<1
	Operate own business	40	1	<1
Size of Company:	Under 500 employees	543	16	15
	500 to 5000 employees	1099	33	33
	5000 to 50,000 employees	1070	32	31
	Over 50,000 employees	631	19	21

Size of Company

Here again an interesting correlation is brought to light: the larger the company, the higher the salary (see Fig. 9). Separate plots of the returns from the under 500 employee companies and from those with 500 to 5000 employees shows these to lie quite close together and to cross several times, although the *under 500* curve does lie $800 below the *500 to 5000* curve, on the average. For the sake of clarity, these curves have been combined into one *under 5000* employees curve.

Other Professional Income

Only 366 returns, or about 10 pct of the total, indicated *other professional income* in addition to salary income. The median *other professional income* of this group, irrespective of age, was $2,500. As noted earlier, 147 of these returns were from educational institutions having a somewhat higher median—in the neighborhood of $3,100.

A small group of returns (51) indicated *other professional income* as the only source of income. These were excluded from the general analysis which deals only with salary income. The median income of this group was $18,000, the average $24,000. The large majority of these returns were from self-employed consultants and those operating their own businesses.

Concluding remarks

This survey has shed light on the particular composition of The Metallurgical Society in terms of the educational background and present professional environment of its members, and it has established correlations between these factors and the financial compensation received in the year 1959.

The population sample on which the survey is based is probably quite representative of the Society as a whole, since this sample consists of about half the membership. However, the Society itself probably does not represent a balanced cross section of the metallurgical profession as a whole, since, for example, 24 pct in our sample have Ph.D. degrees, 40 pct are engaged in the field of research, 61 pct are managers or supervisors. This latter figure may explain the disparity, already noted in the 1958 survey, between these results and those obtained by the Engineers' Joint Council in their survey *Professional Income of Engineers, 1958*. The EJC Survey contains a more normal ratio of managers to individual contributors since it covered a population of over 190,000 engineering graduates. It is interesting to note that their median salary line for the whole population of engineers surveyed is very close to but slightly below that of the *individual contributors* in the present survey.

It should be noted that much additional analysis is possible with the data available. In particular, a study of interaction effects, such as a comparison of the manager and individual contributor in various types of work would be possible. The present analysis has been confined to exploring the effect of single variables on the whole population. If there is sufficient interest in analyses of several factors in combination, it may be possible to present these at a future time.

REVIEW OF DUCTILE IRON

The proceedings at the New York University conference, The Technology of Ductile Iron, is to be published late in 1960 by Rheinhold Publishing Co. under the title, **Ductile Iron, A Course in the Metallurgy of Ductile Iron.**

1. THE METALLURGY OF DUCTILE IRON

"What is the effect of the shape of graphite on the properties of cast iron?" This question is paramount to a discussion of the basic metallurgy of magnesium-containing iron and the changes brought about by the magnesium addition.

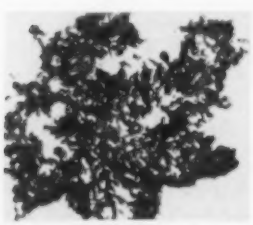
Summary of a paper

by Keith D. Millis

Ductile iron, sometimes called nodular or spheroidal graphite iron, is a relatively new, and increasingly important member of the cast iron family. Ductile iron has the same composition as gray iron but possesses superior strength and ductility. This difference in properties is due largely to the shape of the graphite precipitate—spheroidal in ductile iron; flake form in gray iron.

A number of elements have been reported to be capable of promoting the formation of spheroidal graphite in as-cast iron. These elements include calcium, lithium, sulfur, sodium, magnesium, and cerium. The latter two are the most reliable, with magnesium being most used because of economic considerations, plus the element's ability to form spheroidal graphite in both hypo- and hypereutectic iron.

Carbon has a profound effect on the micro-structure and properties of steels and cast irons. In the simplest case of solidification of iron containing more than 1.7 pct C and cooling to room temperature, the carbon remains in combination as pearlite up to the eutectoid carbon content, and the remainder of the carbon is combined with iron as iron carbide. The carbide is quite hard, has low impact resistance, and good abrasion resistance. A high-carbon iron of this type is known as white cast iron and has many uses, particularly in applications requiring abrasion resistance.



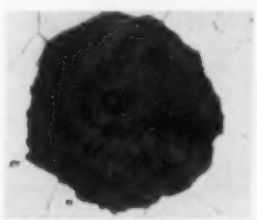


Fig. 1 (left)—Nodular graphite (temper carbon) in malleable iron. 1000X, reduced by 50 pct. Fig. 2 (right)—Graphite spheroid in ductile iron. 1000X, reduced by 50 pct.

KEITH D. MILLIS is with the Development and Research div. of The International Nickel Co. Inc., New York. This paper was presented at the symposium, The Technology of Ductile Iron, arranged by the Dept. of Metallurgical Engineering of New York University in June 1959.

Graphitic cast irons

To obtain graphitic cast irons, the carbon must be allowed to precipitate as graphite. This occurs as the result of a decrease in the solubility of carbon in iron as temperature decreases and solidification occurs. Some elements which are normally contained in cast irons have the effect of further decreasing the solubility of carbon. Silicon is the most powerful and important of these elements. In an iron containing 3.2 pct C and 2.0 pct Si, the solubility of the carbon is low enough that most of the carbon precipitates as graphite rather than being retained as massive carbide in the casting, unless the rate of solidification is so rapid that there is insufficient time for graphitization to occur.

The urge to graphitize increases as the carbon content and/or silicon content of the iron increases. Silicon is, for practical purposes, recognized as having about one-third the effect of carbon. A useful factor in interpreting the iron-carbon diagram takes this fact into consideration; it is called the carbon equivalent (CE) and is approximately equal to the total carbon content plus one-third of the silicon content,

$$CE = \text{pct C} + \frac{\text{pct Si}}{3} .$$

A more precise equation for the carbon equivalent would account for the effects of other elements such as nickel, phosphorus, and manganese, but since their effects are much less important, they are omitted.

There are several other practical methods of effecting graphitization in iron. One is called inocu-

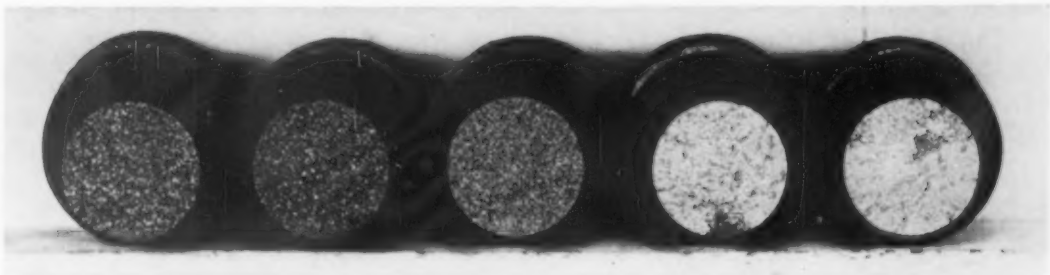


Fig. 3—Fractures of cast iron containing increasing amounts of magnesium from left to right. The iron at the extreme right has fully spheroidal graphite. 1X.

lation, and represents the addition of a graphite promoter to the molten iron just prior to pouring. Although there are many proprietary materials available for stimulating graphitization, the most common inoculant is ferrosilicon containing from 75 to 90 pct Si.

Cast irons which have graphitized in accordance with the discussion thus far contain flake graphite, of which there are many varieties.

Graphite precipitates under certain circumstances in an iron which has retained massive carbide in the solid state. Malleable cast iron is a case in point. The composition of malleable iron is such that when cast in section sizes with sufficiently rapid cooling rates, the carbon is not graphitized, but occurs chiefly as carbide. As would be expected, the carbon equivalent of such an iron is quite low, usually below 3.0 pct, since it is requisite in malleable iron that no graphite precipitate on solidification. When such iron castings are heated to temperatures of about 1650°F and held for relatively long periods of time, the carbide breaks down precipitating graphite. While this graphite is basically flake graphite, the particles are small and exist in the iron as aggregates, relatively widely separated from one another. These are called graphite nodules or temper carbon and are shown in Fig. 1.

Gray cast iron with flake graphite is weak and brittle compared to the properties which could be developed by the iron if graphite were absent. Flake graphite forms almost a continuous network, thus becoming a dominant factor in determining the properties. The distribution of graphite in malleable iron permits continuity of the iron matrix, and since the matrix is then the dominant factor, malleable iron has ductility and resistance to impact far above that of ordinary gray iron. Malleable iron, however, cannot be produced without heat treatment, and as mentioned previously, has section size limitations.

Magnesium-containing irons achieve the type of graphite distribution which is conducive to ductility and impact resistance and accomplish this in the as-cast condition. While the distribution of graphite is somewhat similar to that of malleable iron, the shape of the graphite particle is completely different. Fig. 2 illustrates the graphite spheroids which occur in ductile iron. It is evident from these photomicrographs that the temper carbon nodule is an aggregate of small flakes, and its periphery is relatively rough. The spheroid is a single particle with radial structure and a relatively smooth periphery.

Effects of magnesium additions

Magnesium is a strong deoxidizer and desulfurizer, hence when magnesium is added to such an iron before pouring, it first reacts with the sulfur and oxygen present. Both these compounds are stable, extremely low in solubility in iron, and of low density. Consequently, the major portion of the sulfides and oxide float to the surface of the molten iron and may be readily skimmed off. If sufficient magnesium is added, and under normal procedures, the solidified iron will contain less than 0.02 pct S and generally below 0.015 pct.

When sufficient magnesium is added to the iron so that an amount in excess of that required to combine with the sulfur is retained in the iron, the excess magnesium acts as a carbide metastabilizer. This means that the magnesium promotes the formation of a carbide in the iron, but the carbide is relatively unstable and may easily be made to graphitize by reheating the iron to 1650°F for a short period of time.

However, if, after the iron is treated with magnesium, it is inoculated with ferrosilicon in accordance with the practice discussed for gray iron, the graphite precipitation is complete in the iron as cast. Under these circumstances, a normal foundry iron containing a small amount of excess magnesium, e.g., 0.01 pct, would contain shortened graphite, which has a tendency to be curled. As the residual magnesium increases, the shape of the flakes is further affected, accompanied by an increase in strength. Finally, with sufficient residual magnesium, the graphite precipitates as spheroids. This sequence of change in graphite form is evident in the fractures of the irons. As the magnesium increases, accompanied by its effect on the graphite form, the fractures of the irons change from black to white. This is illustrated in Fig. 3, which shows fractures of five irons with increasing magnesium contents; the whitest fracture has completely spheroidal graphite. The total amount of magnesium in a normal foundry iron required to cause spheroidal graphite to form is usually about 0.04 pct. If inoculation were omitted, or if for any other reason massive carbides were present in the iron, a reheat to 1650°F would cause them to graphitize in the spheroidal form.

Irons pre-conditioned by various methods require less residual magnesium for graphite spheroidization. A basic cupola is capable of issuing an iron with a sulfur and oxygen content so low that few sulfides and oxides are formed; hence, the iron contains less magnesium in combination with sulfur and/or oxygen. The conclusion is, of course, that in the normal foundry iron part of the 0.04 pct residual magnesium is present in combination with sulfur and/or oxygen, and is not directly effective in causing the formation of spheroidal graphite. It is not

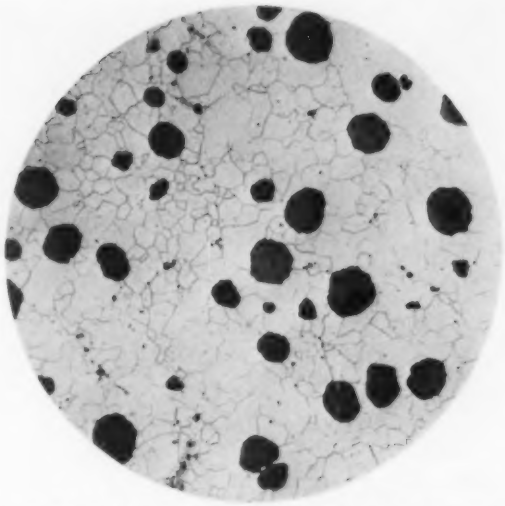


Fig. 4—Spheroidal graphite in ferrite. 250X, reduced by 55 pct.

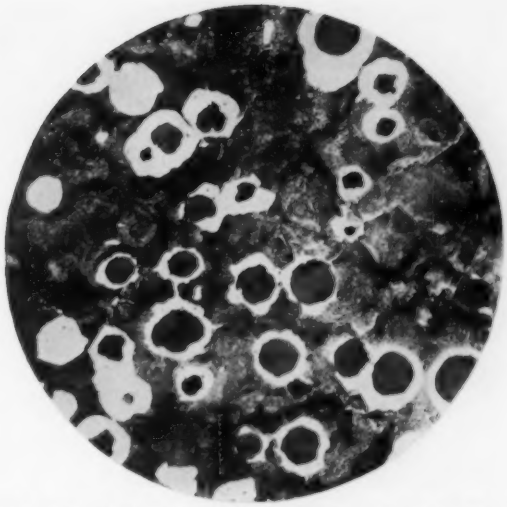


Fig. 5—Spheroidal graphite in pearlite. 250X, reduced by 55 pct.

uncommon to find spheroidal graphite with as little as 0.02 pct Mg in preconditioned irons.

Effect on properties

To simplify the discussion of the effect of magnesium additions on cast iron, let us consider a typical composition which might issue from any cupola. Such a composition might be 3.5 pct C, 1.75 pct Si (2.5 pct after inoculation), 0.7 pct Mn, 0.08 pct S, and 0.08 pct P, balance essentially iron. Such an iron would produce gray cast iron with flake graphite, having a tensile strength of about 20,000 psi and nil ductility. When the graphite is made to be spheroidal, this same composition is capable of developing 100,000 psi tensile strength with 2 to 6 pct of elongation and is readily machinable. A simple heat treatment could be applied to the iron to develop 70,000 psi with at least 15 pct elongation.

The occurrence of graphite in the spheroidal shape changes completely the mechanical properties of high-carbon irons, as compared to those containing flake graphite. As stated previously, graphite in flake form is a dominant factor in determining the properties of gray irons. The almost continous network of flake reduces drastically the continuity of iron matrix, so that in fracture the failure proceeds from flake to flake impeded by only a small amount of metal between. In addition, the flakes are sharp edged, presenting, in effect, a multiplicity of internal notches in the iron. The iron matrix in spheroidal graphite iron is effectively continuous, so that its properties are almost completely developed, decreased only by the amount of iron replaced by graphite spheroids in a given cross-sectional area. The spheroids are essentially smooth and, as such, are not prone to produce a notch effect.

In tension, a flake graphite iron does not exhibit elastic characteristics. There is no true modulus of elasticity and no yield strength, although formulae have been developed arbitrarily to provide safe design figures for these properties. It has relatively low toughness and nil ductility.

Ductile iron with spheroidal graphite has the same elastic characteristics found in steel; it has a definite modulus of elasticity . . . a measurable yield strength . . . good toughness . . . and high ductility, if desired.

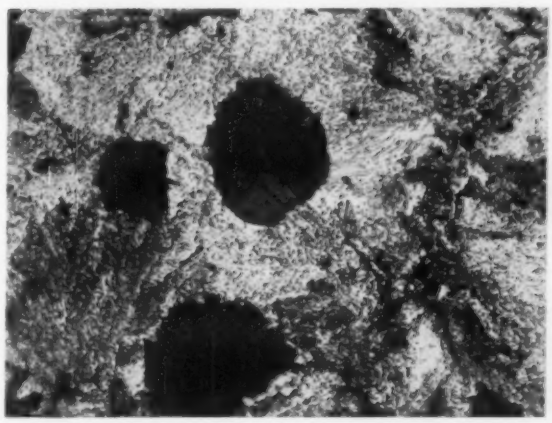
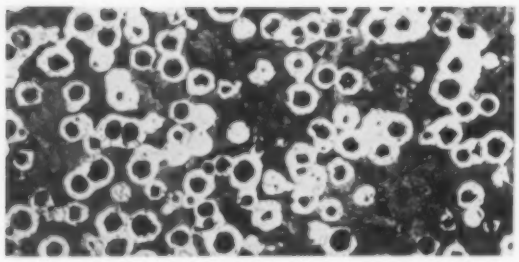


Fig. 6—Spheroidal graphite in fully pearlitic matrix. 250X.

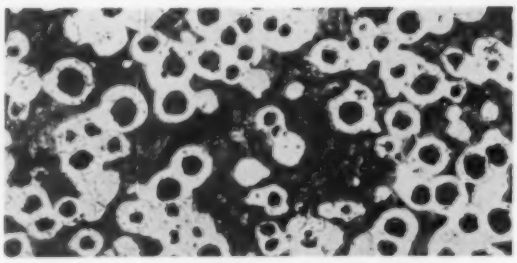
Ductile iron, a family of materials

By varying composition and/or by the use of various heat treatments, spheroidal graphite iron can be made with tensile strengths varying from about 50,000 psi tensile strength with 30 to 35 pct elongation to about 200,000 psi with very little ductility. The normal commercial ductile irons today vary generally from 65,000 psi tensile strength with 20 to 25 pct elongation to 150,000 psi with 1 to 3 pct elongation.

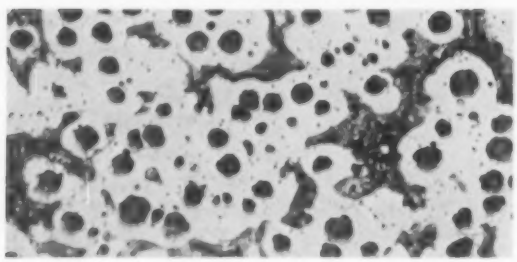
The properties of steel are controlled to a large extent by composition and/or heat treatment, which dictates the form taken by the iron matrix. A low-carbon steel matrix is composed primarily of ferrite, which is the soft, ductile form of iron. It has, relatively speaking, low strength and high ductility and is the most common of the steels. The microstructure of the ferritic type of ductile iron is shown in Fig. 4. The similarity of the matrix structures of the ferritic steel and the ferritic ductile iron is evident. If the composition of the ferrite were the same in each case, the properties of the ductile iron would be lower only to the extent to which the graphite spheroids are substituted for ferrite.



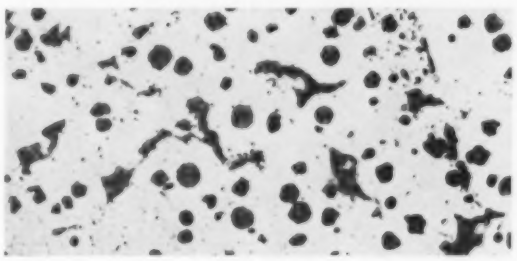
A
5.0 pct Elongation



B
9.5 pct Elongation



C
14.0 pct Elongation



D
22.0 pct Elongation

Fig. 7—Spheroidal graphite in microstructures varying from essentially pearlite to essentially ferrite. 50X.

A carbon steel containing about 0.83 pct C—the eutectoid composition—has a microstructure composed of pearlite. This structure, which is composed of alternate layers of carbide (Fe_3C) and ferrite, is relatively hard and strong with considerably less ductility than ferrite. Fig. 5 shows the matrix structure of a normal pearlitic ductile iron, and, again, the matrix structure is similar to that of the steel, but contains spheroids of graphite, with white areas of ferrite around the spheroids.

It is necessary to reduce the tendency for pearlite to graphitize when the ductile iron's application requires a complete pearlite matrix. This is accomplished by heat treatment or by compositional control, that is, by adjusting the ratio of the amounts of pearlite-promoting and ferrite-promoting elements in the iron. Fig. 6 illustrates a completely pearlitic ductile iron which contains less than normal silicon—a ferrite former—and more than normal nickel—a pearlite promoter.

Ferritic ductile irons are used for applications requiring good strength with high ductility and toughness. The pearlitic ductile irons are used when higher strength levels are needed and resistance to wear is required. Between the extremes are applications which require combinations of the two. These are satisfied by ductile irons having varying percentages of ferrite and pearlite in the microstructure. A series of such variations is shown in Fig. 7. The change in properties with increasing amounts of ferrite in the matrix is tabulated below:

From Fig. 7	Tensile Strength, Psi	Elongation, Pct	Hardness, Bhn
A	96,100	5.0	228
B	85,800	9.5	196
C	77,700	14.0	187
D	69,900	22.0	163

Steel's hardest and strongest matrix structure resulting from heat treatment is martensite. Fig. 8 is the microstructure of a martensitic ductile iron and shows the graphite spheroids in a matrix of martensite. This particular iron was oil-quenched from 1600°F to produce this structure, which is high in hardness; it is used in applications requiring a high degree of resistance to wear and abrasion. Very often, only parts of castings will be made martensitic, either by flame or induction hardening or by selective hardening. Dies and gears which are flame-hardened for wear resistance are not uncommon. To satisfy the applications which require higher strength and hardness than the pearlitic ductile irons but do not require the properties of martensite, any level of properties between the two can be readily achieved—from 140 to over 500 in Bhn with corresponding mechanical property levels.

Effects of commonly-present elements

It has been mentioned previously that, in many cases, desired matrix structures can be obtained by proper control of composition. We should now consider the elements which are normal to the compositions of high carbon irons.

Carbon: In flake graphite irons, the carbon content has a large effect on the tensile strength. As the carbon content increases, the continuity of the graphite flake network becomes more complete and the tensile strength decreases. The highest-strength gray irons contain carbon contents below 2.8 pct. In ductile iron, an increase of carbon content has relatively little effect on mechanical properties. Since high carbon content promotes graphitization—thus decreasing the possibility of retained carbide in the castings—most ductile irons contain from 3.3 to 4.0 pct C.

Silicon: In discussing the effects of elements on ductile iron, silicon should be considered with carbon, since some of their effects are interrelated.

The higher the carbon equivalent above 4.3 pct (hyper-eutectic), the greater is the tendency of the iron to graphitize. Hyper-eutectic irons are recommended for thin section castings, which require the most graphitizing propensity. In heavy

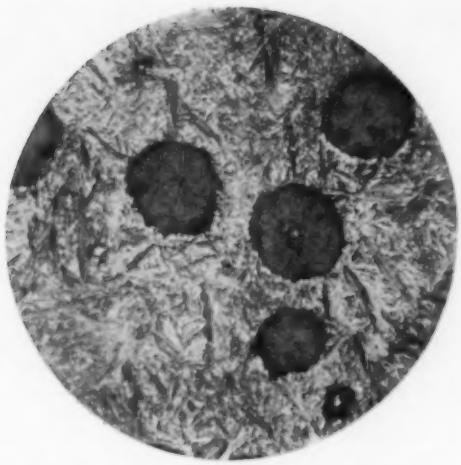


Fig. 8—Spheroidal graphite in martensite. 750X, reduced by 65 pct.

sections whose slow rate of cool and solidification promote graphitization, hyper-eutectic compositions are recommended to prevent flotation of graphite to the upper portions of the casting.

Silicon in ductile iron strongly promotes ferrite and, therefore, is an important element for alloying purposes. Increasing silicon in ferrite increases the tensile and yield strengths and decreases mildly the ductility. It must be used for this purpose with care, however, because a high silicon content in ferrite has a hardening effect and may drastically reduce the resistance to impact.

Manganese: Manganese is present in gray irons to neutralize the effects of the sulfur normally present. Manganese sulfide is formed and the manganese so combined has no effect in determining the matrix structure. In ductile iron, the amount of effective sulfur is nil, since the magnesium addition causes its elimination. Manganese is, therefore, free to exert its influence on the matrix structure in ductile iron. It promotes pearlite. If the normal amount of manganese in gray iron (0.7 to 0.8 pct) is present in ductile iron, the iron will be quite pearlitic. There are instances when this is desirable, and manganese may then be used as an alloying agent. Most of the ductile iron produced commercially contains 0.3 to 0.4 pct Mn, unless a highly-ferritic matrix is desired in the as-cast condition—in which case manganese is kept at a low level.

Sulfur: Since this element is largely eliminated from the iron by the magnesium addition, it need not be considered.

Phosphorus: Phosphorus forms an eutectic phase, called steadite, which is one of the last phases to solidify. The steadite is a hard, brittle phase which reduces toughness and ductility, and cannot be eliminated by heat treatment. It is recommended that the phosphorus content be kept as low as possible and certainly below 0.08 to 0.10 pct. At higher levels, embrittlement becomes significant.

Nickel: Nickel is often added to ductile iron as an alloying element or may be present in ductile iron as a result of the use of a nickel-magnesium alloy for making the magnesium addition. Nickel promotes pearlite and improves the response to hardening heat treatments. The pearlite which is present in the iron as the result of the nickel content is not as stable at elevated temperatures as that promoted by manganese and, therefore, responds much better to a ferritizing anneal.

Molybdenum: This element is often used in ductile iron in conjunction with nickel to improve further the response to heat treatment, particularly in heavy sections.

Chromium: Chromium is a powerful carbide former in ductile iron. The carbide which forms is very stable and practically impossible to eliminate by heat treatment. The chromium level in ductile iron is kept as low as possible, and unless some carbide is desirable in the casting, is always kept below 0.05 pct.

Copper: Copper is a powerful pearlite stabilizer. A copper-containing ductile iron responds poorly to ferritizing heat treatment, and most producers prefer to keep copper levels very low. As will be shown presently, copper can have a deleterious effect on the formation of spheroidal graphite.

Tin: While at the moment tin is not used to any extent in ductile iron—at least in the US—investigators have shown that it is a very powerful promoter of pearlite. It has been reported that as little as about 0.03 pct Sn in ductile iron will cause the matrix to be essentially pearlitic. Care must be exercised in its use, since an excess can have a deleterious effect on the graphite form.

Elements to avoid

There are a number of elements which are known at present to have a deleterious effect on the formation of spheroids of graphite in magnesium-containing irons; these elements appear to fall into two classes:

In one case, the element is one which has an effect of its own in determining the form that the graphite will take. When this form is other than spheroidal, the element and magnesium are in conflict in determining the graphite shape. If the magnesium dominates completely, the graphite will be spheroidal. If not, the graphite can take any number of shapes from deteriorated spheroids to flakes. Elements which fall in this class are titanium, aluminum, copper, and lead. Of course, lead is the element which can be the least tolerated.

In the other case, the element is one which combines with magnesium to form a stable compound. Magnesium thus in combination is unable to exert its influence on the form the graphite is to take. A list of these elements would contain antimony, sulfur, and oxygen.

A small amount of cerium added to the iron, generally with the magnesium, is effective in some measure in overcoming the deleterious activities of these elements.

Conclusions

This paper has illustrated the effects that a mere change in the shape of graphite particles has on a high-carbon cast ferrous material. Among the properties drastically affected by a change from flake to spheroidal graphite are strength, ductility, toughness, modulus of elasticity, heat resistance, machinability, and hardenability.

In effect, the occurrence of spheroidal graphite in a cast-iron composition transforms the material into one with properties similar to those of steel. By control of composition and/or by alloying and/or by the use of heat treatment, spheroidal graphite irons can be produced with a wide range of properties.

2. MAGNESIUM TREATMENT TECHNIQUES

The method of magnesium introduction plays an important role in the production of low-cost ductile iron. This article describes several such methods, showing the attendant advantages and possible savings.

Summary of an article by R. W. White

In the production of ductile iron, the method of introducing magnesium into the iron plays as important a part as the method of melting. Since magnesium is only slightly soluble in iron, a carrier compatible with both iron and magnesium is necessary in order to insure that the magnesium is added safely and in controlled amounts.

Various alloys have been developed since the advent of ductile iron, but today's usage is centered on two types of alloys that give the most satisfactory results. These alloys are categorized as nickel alloys or ferrosilicon alloys. Table I is a list of the various alloys now used commercially.

There are four basic methods of magnesium treatment: transfer, plunging, pressure, and injection; they are discussed in the following sections of this article.

Transfer method

There are a number of transfer techniques for treating iron with magnesium. One of these is the Pensotti technique, which is unique in its precise temperature control. The melting unit is an electric furnace. All of the iron is transferred to a ladle, and when it reaches the desired temperature it is poured back into the furnace onto the alloy. The iron is inoculated with ferrosilicon when transferred back to the hot ladle. There is practically no temperature loss.

With the Sulzer technique, the addition of all the alloy to a portion of the iron at a low, controlled temperature results in a high recovery. Later, untreated iron of high temperature is added to bring the total weight to the desired level. This technique is applied to all methods of making ductile iron, whether by the common method of transfer using nickel alloys . . . by plunging using nickel alloys, ferrosilicons or briquettes . . . or by the pressure method using pure magnesium. The Sulzer technique lowers alloy costs by treating at lower temperatures and reheating by the addition of untreated hot metal.

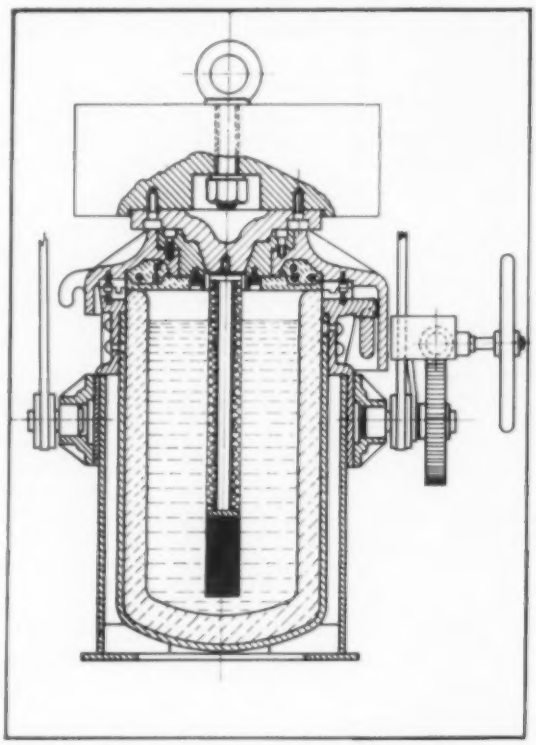
The Kristiansands technique employs over-treatment using the ferrosilicon magnesium alloy. The iron is heated to 2900°F, and one-third of it is

R. W. WHITE is with The International Nickel Co., Inc., New York. This paper was originally presented at the symposium, The Technology of Ductile Iron, arranged by the Dept. of Metallurgical Engineering, New York University, in July 1959.

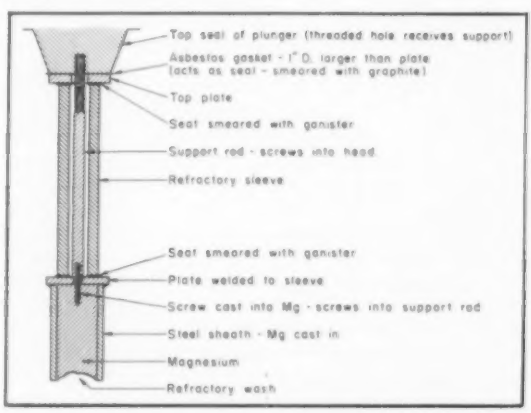
Table I. Nickel and Ferrosilicon Alloys Used in the Production of Ductile Iron

Alloy	Mg, Pct	Ni, Pct	Si, Pct	Ce, Pct	Ca, Pct
NMA No. 1	13-16	80-85	0.5		
NMSA No. 2	13-16	50-55	26-33		
FeSiMg[1]	7.5-10.0		42-47		1.0-3.0
FeSiMgCe[1]	7.5-10.0		42-47	0.5-1.0	1.0-3.0
FeSiMgCe[2]	16-20		60-65	0.5-1.0	3.5-4.5
EM55[2]	30-32		60		4.0-5.0
Magnesium	98-100				

[1] Produced by several companies.
[2] Developed specifically for plunging.



Above, Schuchtermann & Kremer-Baum (SKB)-type sealed ladle with plunger in the inserted position. Below, plunger assembly for the SKB-type sealed treatment ladle.


Top seal of plunger (threaded hole receives support)
Asbestos gasket - 1" O. larger than plate (acts as seal - smeared with graphite)
Top plate
Seat smeared with ganister
Support rod - screws into head
Refractory sleeve
Seat smeared with ganister
Plate welded to sleeve
Screw cast into Mg - screws into support rod
Steel sheath - Mg cast in
Magnesium
Refractory wash

tapped into a pouring ladle and held until the temperature falls to 2450°F. It is then poured into a larger ladle on top of the 9-pct Mg alloy. After the reaction, the ladle is filled with the balance of the iron. The mixed iron is then transferred while adding the ferrosilicon inoculant. Although nearly a 3 pct alloy addition is necessary, it is relatively cheap, compared to the nickel alloy, and results in a savings of 50 pct over the conventional transfer method with No. 1 nickel alloy.

Plunging method

The greater density and slower reactivity of nickel alloys has given them favor when the transfer method was employed. But with the advent of plunging, density has little bearing on magnesium recoveries, and nickel alloys lose their advantage over the ferrosilicon alloys. Development of the plunging method has been followed by the use of alloys with higher magnesium content. Besides the EM55 developed in Germany, there are now available the 16 to 20 pct magnesium ferrosilicons and other alloys which look favorable for further reducing alloy costs.

Probably the first plunging method was developed by the Ansaldo foundry in Italy early in 1952. With this technique the required weight of magnesium chips (with silicon inoculant incorporated into it) are rammed into a fabricated metal basket, which is used for the plunging. This operation has been very successful in Italy and is still employed there.

S. Russell & Sons, Ltd. uses a technique devised in Japan which consists of plunging a prefabricated briquette of granulated magnesium bonded with resin. The granulated magnesium is mixed with 30 pct thermosetting resin and placed in a tapered circular mold for setting. After setting, the briquette is removed from the mold and thoroughly baked. It is then placed in a plunger of appropriate size and plunged into the iron. The reaction lasts about 2½ min when double-treating 1000 lb of iron. The iron is then diluted with another 1000 lb of untreated iron of higher temperature.

The British Westinghouse Brake & Signal Co. employs a unique method of treating 750-lb ladles of iron with pure magnesium ingot. The 0.35 pct Mg is divided into six ingots, none exceeding ½ lb. The ingots are fastened to ⅜-in. diam steel rod with wire. The assembly is heated and then coated with about ⅛ in. layer of resin-bonded sand. The bottom of the magnesium ingot is cleaned to leave an exposed surface to start the reaction. These individual ingots are plunged by hand into a deep, covered ladle containing iron at a temperature of 2800°F. The six plungings require about 2½ min. A small addition of No. 1 alloy is used for insurance.

Pressure method

The idea of adding metallic magnesium within a closed vessel was first conceived by Zwicker of Metallgesellschaft in Germany and developed by Klingbeil of Schuchtermann & Kremer-Baum employing a sealed-ladle principle wherein the formation of magnesium vapor at the high metal temperature forms its own pressure. The English have improved the design in that the lid always remains on the ladle until relining is necessary. The usual treating temperatures are on the order of 2550° to 2650°F, with corresponding vapor pressures of 120 to 160 psi, but the ladles are built to withstand 30 atm or 440 psi.

With regard to the assembly of the plunger and the form of magnesium added, a steel sheath containing the magnesium is fastened to a steel support rod, which can be sheathed in various materials, such as fireclay tile or graphite. The support rod is fastened into the top seal of the ladle. The whole assembly is coated with ganister, as is the exposed end of the magnesium billet. This protects the plunger to prolong its life and retard the reaction until the seal has been accomplished.

The procedure is not spectacular; no smoke or flare is seen during the reaction. The plunger is maintained in the sealed position for a predetermined time, based on 1 min for each 3.33 lb Mg per ton of iron treated—plus a margin of 2 min. This usually requires 7 to 9 min for over-all treatment, i.e., treating 1500 lb of iron to be diluted to 3000, 4500, or 6000 lb of iron. When the plunger is removed, there is nothing to be seen, since magnesium fume and flare is absent.

Another pressure method was conceived by Maurice Grandpierre of the Société des Fonderies de Pont-à-Mousson in France. It is described in some detail in another article in this issue.

Injection

Schrieber of Tirolen Rohrenwerke u. Metallwerke in Austria devised the idea of introducing magnesium powder into a stream of nitrogen which passes through an air-cooled, refractory-sheathed tube into the molten iron. This process is called a lance injection and is a unique technique for introducing metallic magnesium into molten iron. Although this technique does reduce alloy costs considerably compared to the transfer method, maintenance problems and excessive temperature loss have prevented it from growing into a popular treating method.

Several US companies have developed equipment and techniques for using the injection method, and perhaps this method will eventually grow into a popular method of treating.

A comparison

In the US, the preferred method is still to transfer the iron onto the alloy. However, some 5 pct of the producers are using the plunging method, and there is a slow but steady growth. Until recently there has been little concern about lowering alloy costs, but when producers become aware of the tremendous savings in alloy costs, they will also plunge the alloy.

As in Europe, the pressure method has shown little progress in the US, and there are only two pressure vessels in use at the present time. It should be noted that there is considerable reduction in alloy costs by using pure magnesium in a pressure vessel over the conventional transfer method. There are, however, billet and plunger preparation costs. One of the difficulties, and probably the major reason that this method has not developed, is that it is time consuming and seems to require more labor than other methods.

Plunging and pressure methods produce a cleaner iron. Magnesium recoveries are considerably better with these methods than with the transfer method, and this is partially due to the elimination of oxidation during the treatment. As a result, less magnesium oxide slag is generated, thus lowering the hazard of slag entrapment in the castings.

Recent Research

For the past two years, we have been working on a method to introduce pure magnesium into iron which incorporates both the plunging and pressure methods. Laboratory work indicates that it is a step in the right direction.

By this method, the equipment used for plunging is utilized. The initial high cost of pressure equipment, its maintenance, and cost of preparing the magnesium billet is eliminated. It is entirely feasible that the cost of the plunging chamber (when amortized on the basis of a ton of treated iron) will be on the same order or better than that for the present plunging bell. Equipment has been made to treat a ton or more of metal on a commercial basis to determine production problems and work out methods for eliminating them. If this development reaches a successful conclusion, it will become possible to treat a ton of iron with 2 lb Mg, which is getting close to the 1 lb Mg usually retained in a ton of ductile iron.

Inoculation

Ductile iron must be inoculated to minimize casting problems. As a result of the magnesium addition to the iron, the chilling propensity is increased—with possible detrimental effects on the successful founding of some types of castings. Problems such as excessive shrinkage, dross, cracked castings, pin holes, and pattern shrinkage may be encountered.

Many different inoculants have been tried for inoculating gray irons, ferrosilicon having been the most successful in usage throughout the industry. It is a well known fact that a minimum of 0.5 pct Si should be used to eliminate the chilling effect. As the silicon is increased, better results are obtained, and it is now established practice to inoculate with 0.85 pct to 1.2 pct Si in order to get well-formed spheroids and control the amount of chill in the matrix, as would be done with any high-strength iron.

Effective inoculation is obtained when the inoculant is distributed over the complete length of transfer in such a way that it is all mixed intimately with the iron. Earlier experience showed that methods such as putting the ferrosilicon inoculant in the ladle and pouring the iron on it did not inoculate effectively, although very good silicon recoveries were obtained.

* * *

In closing, it should be mentioned that literally dozens of techniques and many different alloys have been developed for making ductile iron. Only those used extensively throughout industry have been discussed.

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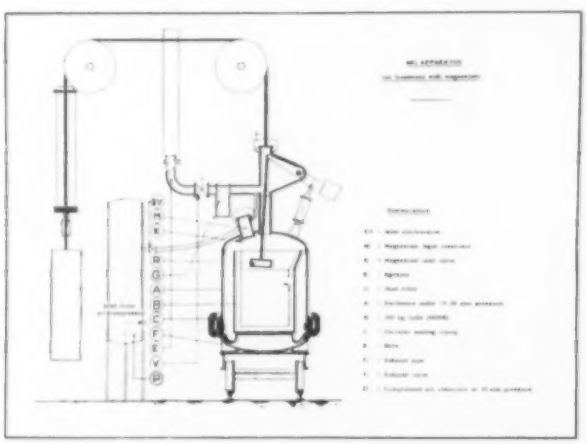
3. PRESSURE CHAMBER TREATMENT IN FRANCE

A Staff-Written Survey



An 800-kg treatment vessel, opposite page.

A great future for ductile iron pipe is foreseen by Europe's largest producer of cast-iron pipe, the French firm, Pont-à-Mousson. Since the development of ductile iron in 1948, this firm has conducted extensive research on production techniques, as well as the physical properties and corrosion resistance of pipe made of ductile iron.

A problem of fundamental importance in the production of ductile iron is, of course, the iron itself, since its composition must be particularly low in sulfur and phosphorus. This presents a very special problem for a plant such as that at Pont-à-Mousson in eastern France, where iron production is based on the smelting of adjacent deposits of high-phosphorus Lorraine ore. But this is not a new problem for the plant, since its cast-iron pipe production also requires a low-phosphorus iron. Thus, some years ago a most interesting metallurgical operation was developed for the production of *synthetic iron*—a recarburized thomas steel. For ductile iron, this same synthetic iron is used after careful adjustment of the silicon content.

Pont-à-Mousson blast-furnace iron, containing 1.8 to 2.0 pct P, desulfurized in one or more stages either with sodium carbonate or powdered lime according to the IRSID process. Further treatment follows the traditional basic-bessemer or thomas process to produce a low-carbon steel containing less than 0.1 pct P. This steel is recarburized by pouring it into a bed of glowing coke in a tall, 15-ton converter. Ferrosilicon is generally added at a later point to bring the composition of the synthetic iron to 0.7 pct P, 1.8 to 2 pct Si, 3.6 pct C, and 0.25 pct

Mn. This synthetic iron is held in a mixer for magnesium treatment, or is cast for later cupola remelting and magnesium treatment at one of the firm's other foundries.

Inoculation process

During the first few years of production, inoculation was accomplished by the addition of Fe-Si-Mg, Ni-Mg, or Cu-Mg alloys which were fusible at the temperature of molten iron. One of the simplest inoculation techniques was the addition of the alloy at the bottom of the ladle, but mixing was not effective, particularly for a heavy alloy such as Ni-Mg. Furthermore, the efficiency of the magnesium—the ratio of the magnesium effectively present in the iron after inoculation to the quantity of magnesium added—is relatively low, and the price of magnesium in the form of such alloys is very high. Nevertheless, this technique is still used for the production of alloyed ductile irons.

When the quantities to be produced are large enough, the inoculation process now used by Pont-à-Mousson is that developed by Maurice Grandpierre. The process employs magnesium in its most economic form—the ingot—and attains a high-degree of efficiency. Grandpierre's idea was that the formation of magnesium vapor might be inhibited entirely if the treatment were carried out in a chamber in which the pressure could be built up to a greater degree than would be obtained by the vapor pressure of the reaction.

With the Grandpierre process, the desired amount of iron is poured into a ladle on a specially-constructed treatment buggy which is moved to the inoculation post. There a steel cover is dropped over the ladle, closed, and locked to the buggy by hydraulic means. Inside the cover the pressure is built up to about 250 psi, and the magnesium is immersed in the iron. A plunger is moved up and down to help agitate the iron and assure a thorough mixing of liquid magnesium and iron. Originally, argon was used to provide the high pressure atmosphere; however, compressed air was later found to be satisfactory and is now in regular use.

The ladle is in the chamber a total of 2 min, and a complete cycle requires 6 min, hence 10 treatments per hr. Pont-à-Mousson has built two sizes of inoculation equipment for its operations: one for 800–kg lots for small-diameter pipe and fittings; the other for 3000-kg batches for large-diameter pipe. Maximum industrial output of the larger unit is about 25 metric tons per hr.

It is possible to overtreat the iron, i.e., to introduce into the iron a greater quantity of magnesium than that required for treatment. On this basis, 1½ tons of iron can be treated in a 3-ton ladle with sufficient magnesium to treat 3 tons, and the treated iron can later be diluted to 3 tons by mixing it with untreated material.

The consumption of magnesium is a function of the quantity of sulfur in the untreated iron. On an average, it is necessary to add magnesium in amounts varying from 0.15 to 0.25 pct of the weight of the iron, i.e., 1.5 to 2.5 kg of Mg per metric ton of iron treated. For a residual magnesium cotnent of 0.06 pct, the efficiency of magnesium varies from 30 to 60 pct. Analysis of the iron, and the magnesium in particular, is accomplished rapidly by means of a spectroscope in order to provide the precise control required in ductile iron production.

Pipe production

Ductile iron pipe is cast in the same general fashion as ordinary cast iron pipe, i.e., by the De Lavaud method of centrifugal casting in a metallic mold. But differences in the physical properties of ductile iron require certain modifications in the operation. Among the principal differences is the necessity of preheating ductile iron to 1250° to 1350°C in an electric furnace before centrifugation. After casting, annealing of the pipe is accomplished in two steps: a graphitization heat at 950°C, followed by ferritization at about 750°C in a second furnace.

Ductile iron pipe has been cast for several years in diameters ranging from 1 to 24 in. at an output of 20 to 30 metric tons per hr. Recently, a new pipe-casting machine has been placed in operation for the production of diameters ranging from 24 to 50 in.

Fittings, valves, and other castings of ductile iron are made by iron melted in a cupola and inoculated with magnesium according to Grandpierre's process.

Markets

The excellent mechanical properties of ductile iron pipe mean ever expanding markets. Today it is largely used for applications requiring:

a) high pressure resistance;
b) high impact strength, which prevents breakage during transport and provides greater security against ground movement;
c) corrosion resistance; and
d) resistance to thermal shock.

Application of ductile iron pipe in petroleum tankers where it must resist stresses and repeated tension caused by ship movement is a particularly interesting use. Made of a certain quality of ductile iron, these pipes have been found to provide excellent resistance to corrosive conditions encountered on petroleum tankers.

Applications have confirmed the many excellent qualities of ducile iron pipe. Particularly appreciated is their steel-like strength combined with cast iron's traditional ease of casting and resistance to corrosion. F. W. S.

Nuclear Congress Features Industry Displays, Papers

A total of 5000 persons looked at and tried out an array of nuclear apparatus ranging from digital computers to fall-out shelters during the Sixth Nuclear Engineering & Science Conference and Atomic Exposition held at New York's Coliseum April 4-7.

Altogether, 62 papers were compressed into the four days of technical sessions meeting on the Coliseum's fourth floor. The papers revolved around the Congress' theme—the application of nuclear energy for mankind's benefit. They emphasized seven areas: reactor construction, reactor design, environment, materials and components, nuclear standards, isotopes, and radiation processing.

The complete set of papers is still available at 50¢ per paper or $20 for the set. For the list of papers available, write: 1960 Nuclear Congress, 29 W. 39th St., New York, N. Y.

On the second floor of the Coliseum, 150 booths, ranging in size from one unit to sprawling islands, enveloped the space. Among the most lavish of the of the exhibits were those of foreign governments—France and Canada in particular. Some American metals company exhibits are represented in accompanying pictures.

Abstracts from two papers of particular interest to metallurgists follow. Another paper, **Bureau of Mines Research on the Fused Salt Electrorefining of Beryllium,** by Morton M. Wong, Robert E. Campbell, and Don H. Baker, Jr., US Bureau of Mines, Boulder City Metallurgy Research Laboratory, Boulder City, Nev., will be presented in its entirety in a future issue of JOURNAL OF METALS.

* * *

Liquid-Liquid Extraction—Influence of the physical properties variation of solutions on the pulsed column performances, by J. Durandet and X. Talmont, Institut Francais du Petrole & Commisariat à l'Energie Atomique.

Continuous extractors which utilize mechanical means of agitation have been shown to give higher extraction efficiencies than contactors with no external means of producing the turbulence necessary for high extraction rates. One such extractor is the perforated-plate pulse column considered in this paper.

The authors related variations of local efficiency and the physical properties of the uranium along the column. Influences of the ratio increment of density to the density of continuous phase and the ratio of the density of continuous phase to interfacial tension were shown on interfacial area and drop size, and an explanation of the column operation was proposed.

Study of the HETS variation shows that the efficiency of the diluted column sections is low; in order to increase the mass transfer occurring in these column zones, modification of the dispersion in these zones is suggested along the following lines:

Extraction column: as flooding occurs in the concentrated column section, it is probably possible—without lowering the apparatus capacity—to increase the efficiency of the lower column zone either by increasing power consumption per unit mass (for instance the column diameter or the plate design can be modified in this section) or a higher temperature can be used at the column bottom in order to lower the interfacial tension.

Stripping column: it would probably not be efficient to increase the turbulence or values of the ratio of the density increase to the density of continuous phase or that of density of continuous phase to interfacial tension, since flooding occurs in this zone. The lack of interfacial renewal is thought to cause low efficiency. Thus, the top column should be operated with a low pulsation in order to cause coalescence and breaking up of drops. For instance, a larger column diameter in this section could produce the wanted type of flow (mixer-settler type). Another way of causing drop coalescence is to locate the interface in the column plate section; organic and aqueous phases would thus be successively dispersed. Futher investigations are being directed along these lines.

The effect of tributylphosphate dilution on column performance was also studied. The best results (high capacity, good efficiency) were obtained with solvents containing between 20 to 30 pct of TBP.

Preparing High-Purity Thorium by Reduction With Sodium, by P. C. Good and F. E. Block, US Bureau of Mines, Albany, Ore.

The authors described the preparation of thorium tetrachloride by chlorinating calcined thorium oxalate with carbon tetrachloride. In this method for preparing thorium metal, crude thorium tetrachloride (containing oxygen-bearing compounds) is purified by double vacuum distillation at 850° to 900°C. Thorium metal in the form of a dense sponge is made by the reaction of metallic sodium with thorium tetrachloride at 800°C. Vacuum arc melting is used to consolidate the sponge metal into ingot form for evaluating its physical properties.

The starting point in the process involves preparation of anhydrous thorium tetrachloride, essentially free of metallic impurities. Generally, volatile chloride compounds can be prepared by reacting a metal oxide with elemental chlorine in the presence of carbon. By regulating the temperature of this reaction, the chloride product can be removed for the reaction zone as a gas and can be collected as a condensate—leaving any unreacted material and excess carbon reductant as a non-volatile residue. This procedure proved unfavorable with thorium, since its chloride forms a liquid phase at the temperature of the reaction—coating the unreacted particles of the charge and preventing further contact with the chlorine atmosphere. When the tem-

Right, beryllium metal and beryllium oxide have become important materials in the nuclear field. Below, the demand for high-purity refractory metals for nuclear applications is on the increase.

perature was maintained at a level high enough to volatize the thorium chloride rapidly, the reaction became thermodynamically unfavorable, and corrosion of the equipment became a problem.

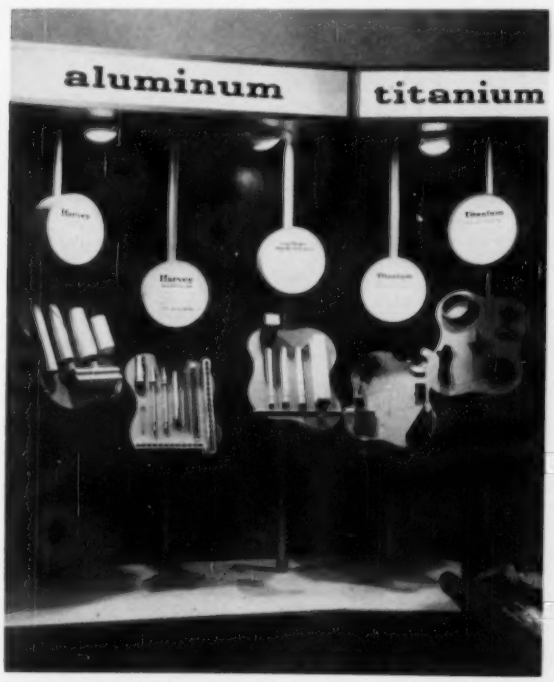
Instead of a high-temperature reaction, designed to remove the chloride from the reaction zone, a batchwise reaction between chlorine, thorium oxide, and carbon at 500°C was found to yield almost complete conversion to solid thorium tetrachloride. This procedure requires a second sublimation step to separate the chloride from the excess carbon reductant. Although it is possible to prepare a chloride feed material by this method, it is difficult to remove all traces of carbon—especially when larger batches are prepared. This difficulty is caused by entrainment of small carbon particles in volatilizing thorium tetrachloride gas.

Under certain conditions, there is fairly rapid release of thorium *daughter* products of moderately high activity. In the procedures described, this occurs mainly in the high-vacuum distillation step used for sponge-metal purification, and in the arc-melting step. Care must be taken in venting vacuum pumps and ventilating equipment to the outdoors through suitable filtering apparatus.

The authors, thus, established the conditions for preparing cold, ductile thorium metal by an inert-atmosphere crucible reduction technique, using either high-purity commercial magnesium or high-purity commercial sodium as reductants. The scale of the reduction step was extended to preparing metal batches of 20 kg. The consolidated metal prepared by this method is readily fabricated to a thin sheet which, after annealing, remains soft and ductile.

* * *

The next Nuclear Congress and Exposition is scheduled for June 1962, according to the Engineers Joint Council, the meeting's principal sponsor. RMS



Harvey showed fabricated shapes of zirconium, aluminum, and titanium.

NEW COPPER REFINERY WITH NEW IDEAS

A Staff-Written Article

Kennecott's new eastern refinery, the second such installation built by the firm in the past decade, already occupies a prominent place in the progressive electrolytic copper refining industry. Here is a description of this modern operation, with emphasis placed on its novel and noteworthy features.

The Country's newest and most modern electrolytic copper refinery—with a capacity of 16,500 tons per month of 99.95 pct copper—was started up in November 1959 by Kennecott Refining Corp., a subsidiary of Kennecott Copper Corp. Present output is at the rate of 10,000 tons per month.

The $30-million plant was designed and built by The M. W. Kellogg Co. in close cooperation with Kennecott's engineers. It incorporates the latest equipment and design features of the industry for maximum efficiency in operation and materials handling. The refinery is located south of Baltimore on the Patapsco river on a 232-acre tract, which provides ample room for future expansion. With present facilities, employment should be approx 570 persons.

Refinery operations are based on the utilization of 99.4 pct fire-refined blister copper—supplemented by anodes—from Kennecott's Western Mining Division operations. The blister comes in by ship to the new Maryland Port Authority pier, where it is transferred to railroad cars. At the plant, these cars, together with those from the West, are unloaded by crane and fork trucks in the outside storage area.

The first and most obvious feature of the plant is the extensive use of special trucks for materials handling. The refinery operates four 45,000-lb straddle carriers and nine fork trucks with a 7000 to 28,000-lb carrying capacity.

Anode casting

Blister cakes from the storage area are transported by fork trucks to the anode casting building where they—together with spent anodes from the electrolytic tanks—are fed into two 400-ton capacity reverberatory refining furnaces by a crane-type charging machine.

The furnaces have metal-clad basic refractory lining including suspended flat roofs. Each furnace is fired by four gas burners (with oil as an alternate fuel), which make possible a complete operating cycle of 22 hr. This includes 4½ hr for actual melting, followed by desulfurization and deoxidation. To reclaim the sensible heat of the flue gases, a 40,000-lb-per-hr waste heat boiler has been installed above each furnace.

The furnace discharges molten copper through launders into the pouring ladle, which casts the copper at 2140°F into the molds of the 46-ft diam anode casting wheel. This 70-ton-per-hr machine produces two anodes every 37 sec. Solidified anodes are cooled by water sprays before a specially-designed anode take-off machine removes them from the molds. This machine grips two plates, tilts them upright, and places them on a chain conveyor, which spaces them automatically at 4¼ in. intervals, a distance maintained throughout the refining operation. At the end of the conveyor, 48 anodes at a time are picked up and placed on bolsters. Straddle trucks carry the loaded bolsters to the tank house, where a 25-ton overhead crane removes them and lowers them into the cells. Straddle trucks return the empty bolsters to the anode casting area.

Final designs are being worked out on a spacing machine for handling incoming anodes. Fork trucks will place the anodes on this conveyor machine. While transporting the anodes to the bolsters, the machine will space them at 4¼-in. intervals. Bolsters with 48 anodes will then be carried to the tank house by straddle trucks.

Tank house

The production section of the new tank house contains 1100 lead-lined concrete cells, divided into sections of 44 cells, connected in series. There are 49 anodes and 48 cathodes in parallel in each cell; the potential drop is approx ¼ v at 19.8 amp-per-sq-ft current density.

The electrolyte, before recycling to the tanks, is treated with glue and orzan, and then heated from 136° to 150°F in coil heaters. The concentration of the electrolyte is kept at 190 gpl H_2SO_4 and 50 gpl Cu by bleeding a portion of it from circulation and passing it through decopperizing tanks. Part of this electrolyte is further processed in liberator tanks to produce so-called *black acid*, a sludge which is shipped out to a smelter, plus a crude nickel sulfate for marketing.

Slimes from the production tanks are leached with sulfuric acid in the traditional manner and sent to precious metal refineries.

Two weeks are required for the deposition of 300 lb of copper on the cathode sheets. These are removed by a crane which places them on the chain conveyor of the cathode washing machine, which washes the cathodes by water sprays. The suspension bars are removed, and the cathodes stacked on bolsters. Straddle trucks transport the loaded bolsters to the casting department.

Starting sheets

The new Kennecott refinery produces its own starting sheets in a separate section of the tank house. Seventy-two cells in two sections are surrounded by a combination of chain and gravity-operated trolley conveyor systems for ease in handling sheets.

The cathode blanks are first oiled, and then lowered by crane into electrolytic tanks. In 24 hr a cop-

per sheet of 0.015-in. thickness is deposited on each side of the cathode blanks, which are removed and later washed on a chain conveyor. After being transferred to the overhead trolleys, they go to the stripping site, where the sheets are stripped by hand from the cathode blanks. The bare blanks are inspected, oiled, and returned to start a new cycle.

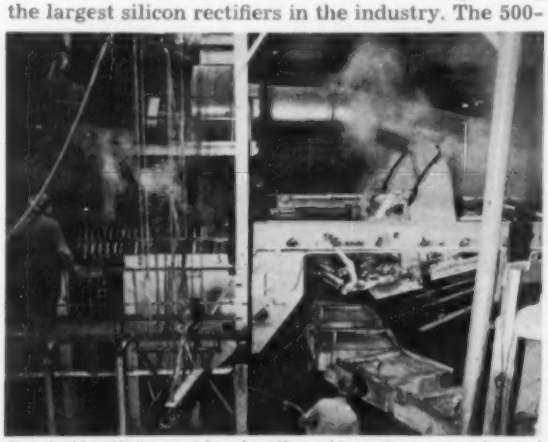
The thin starting sheets are further processed before use in the production cells. Some of the sheets are used for loops on the starting sheet assemblage; these sheets are cut into quarters, bent around copper suspension bars, and fastened to uncut starting sheets. The looping and fastening machine is of new design.

The electrolyte of the starting sheet section is treated separately to maintain a concentration at 150 gpl acid and 40 gpl copper.

Special refinery features

An interesting feature of this new electrolytic refinery is the piping used for the handling of corrosive liquids. Instead of the customary lead piping, Kellogg designed and installed 95,000 ft of PVC (polyvinylchloride) piping for which a special fitting procedure had to be developed. This plastic pipe offers several advantages: it reduces stray currents, does not oxidize, needs fewer supports, and shows no creep in service.

The rectifiers deserve mention too—being among the largest silicon rectifiers in the industry. The 500-



This highly efficient anode take-off machine grips two anodes and places them on the chain conveyor (at left).

kw rectifier for the stripper tanks delivers 20,000 amp at 25 v, while those serving the production cells are of 3000 kw capacity, with 20,000 amp at 150 v. A fifth unit is rated 500 kw at 10,000 amp and 50 v, and serves the Liberator Building. These rectifiers need less space than the usual motor-generator combination . . . are more efficient (approx 98 pct) . . . and can be placed close to the section which they serve, thereby offering substantial savings in buss-bar length. They are very reliable; failure in one of their cells does not cause shut down, since the remainder will carry the load, thus permitting repairs during operation.

Cathode melting

Wire bars and billets—the refinery's two products—are produced in the latest melting and casting equipment. JOURNAL OF METALS has previously described in detail a similar melting installation at Asarco's Perth Amboy, N. J., plant (June 1959, pp. 404-406), and this will not be repeated in the present article.

Cathodes from the tank house are fed by a charging machine into the gas-fired rotary cathode preheating furnace. This charging machine operates automatically and is synchronized with the rotation of the preheating furnace. The cathodes are heated to 1400°F in the 58-ft diam furnace so as to burn off sulfur and economize on the electrical requirements of the arc furnace into which the preheated cathodes are next charged by the same charging machine.

The three-phase, 90-ton electric furnace of 35,000 kva capacity has three 20-in. diam electrodes provided with a special mechanism to maintain a uniform arc. The furnace, besides melting down the cathodes, has provision to adjust the oxygen content of the copper by letting controlled amounts of air sweep over the bath. The furnace discharges liquid metal through launders into 300-kw induction holding furnaces, which maintain the metal at 2140°F for the casting operation.

Tough-pitch copper for wire bars is cast on a traditional-type casting wheel. Solidified bars from the 28-ft diam wheel are immersed in water, inspected on a chain conveyor, and stacked and bundled by a stacking machine.

Continuous casting

The plant also produces deoxidized, high-residual phosphorus copper billets on four continuous billet-casting machines, each fed by a separate induction furnace. They produce 3-in. diam billets at the rate of 50 in. per min through water-cooled graphite molds. The emerging solidified billets are cooled by water sprays and cut to length by flying saws.

The product drops into the receiving basket, which tilts down and discharges the billet onto a conveyor. Every 37th billet is 1½ in. longer; this extra length is cut off and used for inspection purposes. A billet bundling and cupping machine finishes the operation by bundling 37 billets together.

Conclusions

Kennecott's new eastern refinery has extensive automatic controls together with manual stand-bys. A central control panel in the tank house monitors the bath level . . . measures the flow of electrolyte . . . and records current voltage and amperage.

These controls, together with improved materials handling and equipment of the latest design, ensure what is probably the industry's lowest-cost refinery operation.

Cathode washing machine with the clean cathodes stacked on a bolster. The suspension bars are removed by hand.

PURE COLUMBIUM AND TANTALUM OXIDES BY LIQUID-LIQUID EXTRACTION

Complete separation of the metals columbium and tantalum is achieved at the Albany, Ore., plant of Wah Chang Corp. by solvent extraction of the acid fluorides. The effect of acidity on the solubilities of two fluorides is the mechanism of their separation.

by Carl W. Carlson
and Ralph H. Nielsen

ALTHOUGH many methods have been proposed for the separation of columbium and tantalum, only four have received serious industrial consideration. These include crystallization of the potassium double fluorides (which has been used for many years), ion exchange of the acid fluorides, fractional distillation of the pentachlorides, and solvent extraction of the acid fluorides. The solvent extraction process is ideally suited for large-scale production of pure columbium and tantalum oxides and has been adapted by several firms both here and in Europe.

The separation of columbium and tantalum by liquid-liquid extraction involves two fundamental principles. The first is the almost unique solubility of columbium and tantalum acid fluorides in an organic solvent. This can be used to separate these two metals from other metallic elements. The other principle—the effect of acidity on the solubility of columbium and tantalum in a solvent—can be used to make a complete separation of the two metals.

USBM and Canadian studies

Much of the basic investigation of liquid-liquid extraction systems for the separation of columbium and tantalum was conducted at the US Bureau of Mines Laboratories in Albany, Ore., from 1952 to 1954. Approximately 200 combinations of various organic solvents and mineral acids were investigated as possible separation systems in which the columbium and tantalum could be extracted into a solvent from a mineral acid solution. Ketones were found to give the best extraction from hydrofluoric-hydrochloric acid solutions. As shown in Table I, excellent separation was obtained with all of the ketones. Methyl isobutyl ketone or hexone showed the most promise with the highest separation factor at a minimum transfer of columbium. The starting material for these investigations was Geomine tin slags which had been leached and upgraded to about 40 to 60 pct combined oxides. A typical Geomine tin slag analysis is shown in Table II.

A 2-in. diam pulse plate column was assembled and operated at the Bureau of Mines' Albany Laboratory during 1954 to evaluate this system for commercial use. Their conclusions were that tantalum and columbium separation could be accomplished by liquid-liquid extraction, and that an industrial scale-up of the process was economically feasible. Maximum separation of the two elements obtained in the hydrofluoric-hydrochloric acid-hexone system would produce columbium and tantalum oxides of more than 99 pct purity.

In 1956, G. H. Faye and W. R. Inman of the Department of Mines and Technical Surveys, Ottawa, Canada, investigated the extraction of methyl isobutyl ketone with various mixed acid solutions of tin slags. They found that the extracted oxides were most free of impurities when the mineral acid solution was a mixture of hydrofluoric and nitric acids. Sulfuric acid was almost as satisfactory as nitric acid, but hydrochloric acid promoted the extraction of iron chloride along with the acid fluorides of columbium and tantalum.

Wah Chang pilot studies

In the fall of 1956 when Wah Chang Corp. chose to begin production of columbium, a pilot plant was installed at the Albany, Ore., div. to develop the liquid-liquid extraction process into a full scale production operation. After considering the danger inherent in using strong nitric acid with a ketone, the sulfuric-hydrofluoric acid system was selected for further development. Columbite and tantalite ores were used instead of tin slags. A typical analysis of Malayan columbite ore is shown in Table III.

CARL W. CARLSON and RALPH H. NIELSEN are with the Wah Chang Corp., Albany, Ore. This paper was presented at the 1960 AIME Annual Meeting.

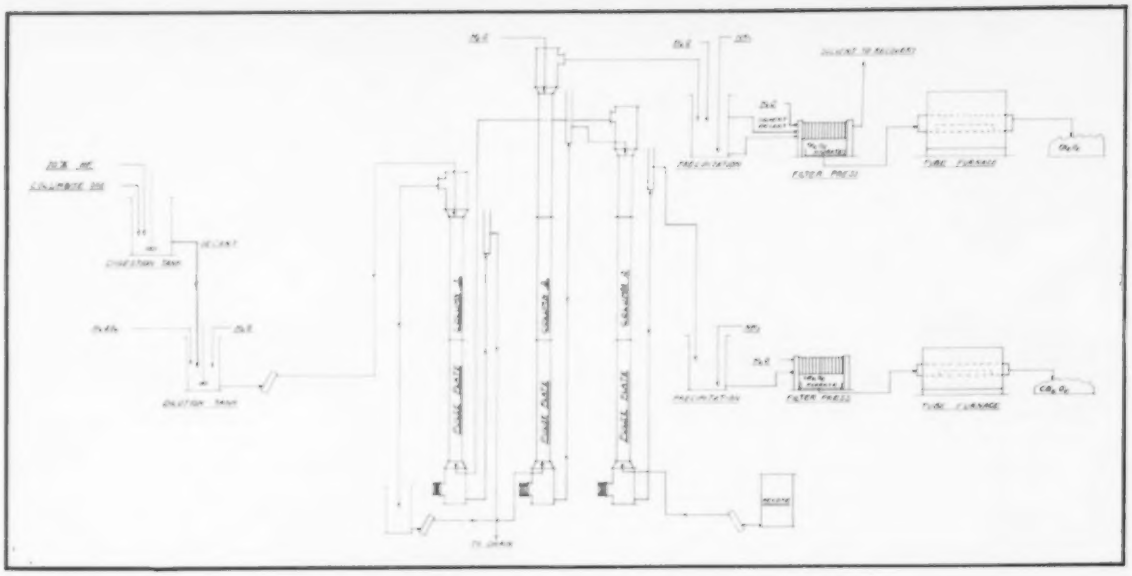


Fig. 1—Schematic flow diagram of columbium-tantalum separation pilot plant.

Tantalite ores have approximately the same impurities, but the tantalum to columbium ratios range from 1:1 to 4:1.

Three pulse plate columns were assembled from 4 ft and 8 ft sections of flanged 4-in. diam polyethylene ducting packed with ⅛ in. thick perforated polyethylene plates spaced 2 in. apart. The plates were drilled with 7/64 in. holes on 11/64 in. centers to give approximately 30 pct open area. The disengaging sections at each end were 6-in. diam polyethylene tees reduced on one end to 4 in. The pulse was supplied by a bellows bolted to the tee and operated by a crank arm connected to an adjustable cam on a gear motor. The frequency was fixed to 58 rpm but the pulse amplitude could be varied from 0 to 4 in. The interconnecting piping and all of the solution tanks were of polyethylene construction. The diaphragm metering pumps for flow control had specially-constructed polyethylene heads. A schematic diagram of the pilot plant is shown on Fig. 1.

These columns were set up to run continuously and perform the following operations: The first column with an effective length of 20 ft was used to extract, countercurrently, the metallic fluorides into hexone from a feed solution which was made up by dissolving columbite ore in 70 pct hydrofluoric acid and diluting to approximately 10 N free acid with water. Dilute sulfuric acid was pumped into the column along with the feed to keep all the other metallic fluorides except the columbium and tantalum in the aqueous phase.

The second column, with an effecting length of 32 ft, was the actual separation column. The solvent containing the tantalum and columbium from the 20-ft column was contacted countercurrently with water, reducing the free acid available in the solvent, bringing about the transfer of all the columbium and a small amount of tantalum to the aqueous phase, and leaving the solvent phase pure in tantalum.

The third column, with an effective length of 24 ft, was used to re-extract with fresh hexone the tantalum out of the aqueous solution coming from the second column. This solvent was recycled to the first column and the aqueous raffinate, pure in columbium, was precipitated with anhydrous ammonia, filtered, washed, and calcined to columbium oxide.

The tantalum was precipitated directly from the solvent with anhydrous ammonia, filtered, washed, and calcined to the oxide. Much difficulty was en-

Table I. Extraction Efficiencies of Various Ketones*

Solvent	Extraction Phase	Total Oxide Contained, g	Analyses, Pct Ta	Analyses, Pct Cb	Weight, g Ta	Weight, g Cb	Metal Transfer, Pct Ta	Metal Transfer, Pct Cb	Separation Factor
Di-isobutyl ketone	Aqueous	2.8429	23.0	31.0	0.655	0.882			39
	Organic	0.0532	63.0	2.2	0.034	0.001	3.8	0.13	
n-Butyl ethyl ketone	Aqueous	2.4881	23.0	40.0	0.572	0.995			149
	Organic	0.4330	78.0	0.9	0.338	0.004	37.1	0.39	
Methyl n-hexyl ketone	Aqueous	2.3997	19.0	38.0	0.456	0.911			228
	Organic	0.5086	81.0	0.7	0.413	0.003	47.6	0.34	
Methyl n-amyl ketone	Aqueous	2.1632	15.0	43.0	0.325	0.932			394
	Organic	0.7434	80.0	0.6	0.595	0.004	64.7	0.46	
Di-isopropyl ketone	Aqueous	2.4953	22.0	41.0	0.549	1.022			361
	Organic	0.4117	64.0	0.3	0.264	0.001	32.5	0.13	
Cyclohexanone	Aqueous	1.5437	1.1	56.0	0.017	0.855			856
	Organic	1.2522	74.0	4.4	0.927	0.055	98.3	6.12	
Methyl isobutyl ketone	Aqueous	1.6671	9.2	52.0	0.153	0.866			736
	Organic	0.8098	78.0	0.6	0.631	0.005	80.6	0.56	

* Reprinted from *US Bureau of Mines Report of Investigations 5239.*

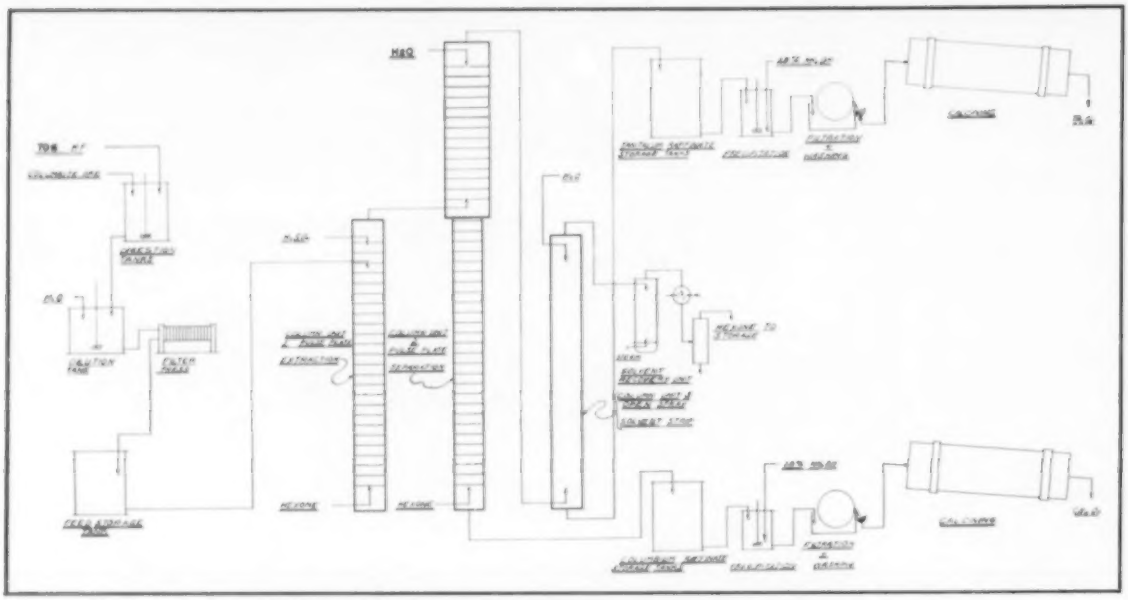


Fig. 2—Schematic flow diagram of full-scale columbium-tatalum separation plant.

countered in filtering this precipitated solvent solution; so, an open column was added in which the solvent containing the tantalum was contacted countercurrently with copious quantities of water—thus transferring the tantalum back to an aqueous solution which could be treated to produce tantalum oxide using the same procedure as for columbium oxide. Composite data for a typical day's operation are shown in Table IV.

Full-scale production

In January 1958 a full-scale production plant capable of producing 3000 lb of combined oxides-per-day was put on stream. The separation process is essentially the same as the pilot plant, except for minor scale-up modifications. A schematic diagram of the Wah Chang columbium-tantalum separation plant is shown in Fig. 2. A brief description of the equipment and typical operating data follows:

Table II. Analysis of Geomines Tin Slag[a]

Chemical

Oxide	Pct	Oxide	Pct	Oxide	Pct
Ta_2O_5	9.2	CaO	15.2	TiO_2	2.5
Cb_2O_5	9.8	MgO	4.3	SiO_2	28.0
Fe_2O_3	11.1	SnO_2	1.9	Al_2O_3	6.4
MnO_2	3.8				

Spectrographic

Element	Pct	Element	Pct
Al	1-5	Mn	1-5
Be	0.001-0.01	Si	>10
Sn	0.1-1	Ti	0.1-1
Ca	>10	V	0.01-0.1
Cu	0.001-0.01	Mo	0.01-0.1
Mg	1-5	Zr	0.1-1
Fe	>10	B	0.01-0.1

[a] Reprinted from *US Bureau of Mines Report of Investigations 5239.*

The feed preparation system consists of agitated monel digestion tanks for feed dissolution . . . agitated wood tanks with polypropylene sheet lining for dilution and acidity adjustment . . . rubber-covered plate and frame filters for removing undigested or insoluble products . . . and wood storage tanks with polyethylene sheet lining for clear feed storage. The diaphragm transfer pumps are Hypalon-lined, and all the piping in the feed make-up system is polyvinylchloride.

The separation system is made up in three pulse-plate column units of all-polyethylene construction. Units one and two are packed with perforated plates spaced 2 in. apart. The plates are perforated with 7/64 in. holes on 11/64 in. centers to give the same pct open area as the pilot plant columns. The interconnecting piping is also made from polyethylene, as are the surge tanks and interface controls. The valves and fittings are made of either polypropylene or Penton.

Diaphragm metering pumps with monel liquid ends not only are used for pumping the solvent to the bottom of each column, but also supply the required pulse for each column. The same type of pump also meters the aqueous acid solution to the top of each column. The storage tanks for both the columbium and tantalum raffinates are of standard wood construction.

The precipitation, washing, filtering, and calcining system consists of agitated wood precipitation tanks, rotary vacuum filters with stainless-steel wetted

Table III. Typical Analysis of Malayan Columbite Ore

Oxide	Pct
Cb_2O_5	58.2
Ta_2O_5	17.4
Al_2O_3	1.2
Fe_2O_3	13.5
MnO_2	3.6
SiO_2	3.0
SnO_2	0.4
TiO_2	1.8
WO_3	0.9
	100.0

Table IV. Typical Pilot-Plant Run—Columbium-Tantalum Separation

	Column 1		Column 2				Column 3			
	Free Acid Normality	Oxide Content	Free Acid Normality	Oxide Content	$\frac{Ta}{Ta+Cb}$	$\frac{Cb}{Ta+Cb}$	Free Acid Normality	Oxide Content	$\frac{Ta}{Ta+Cb}$	$\frac{Cb}{Ta+Cb}$
		gpl		gpl	Pct	Pct		gpl	Pct	Pct
Acid Feed	8.96	91.6								
Solvent Extraction	3.88	80.0	0.17	12.0	>99.8	<0.1	1.08	12.4		24.3
Aqueous Raffinate	5.38	7.0	3.63	72.1	6.0		2.43	65.4	<0.05	>99.8

Pulse Frequency 58 pulse per min; Pulse Amplitude 1.125 in.
Acid Feed Rate 7.0 gal per hr
Solvent Flow Rate 9.7 gal per hr
Aqueous Flow Rate 9.4 gal per hr

parts, wood plate and frame filter presses for polishing the filtrate, agitated wooden wash tanks, and gas-fired refractory-lined rotary kilns for the calcining of both oxides.

British Malayan columbite ore is still used as the primary raw material for the separation plant. However, during the ball milling to −200 mesh enough high-ratio tantalite ores are blended in to bring the columbium to tantalum ratio up from 4:1 to 3:1 with a combined oxide content of approximately 75 pct.

This ore is digested with 70 pct hydrofluoric acid using 2.5 lb acid per lb of ore. Digestion is continued until the combined $(Cb+Ta)_2O_5$ in the solution reaches 3 lb per gal, at which time it is diluted to 15 N free acid, filtered, and pumped to the storage tanks. This dilution is necessary to prevent complete dissolution of the acid feed with the solvent phase in the first extraction unit. An upgrading of the combined oxide from 75 pct to greater than 90 pct is also accomplished in this operation.

This 15 N aqueous solution is pumped from the storage tanks (along with dilute sulfuric acid) to the top of the extraction unit, which consists of two pulse-plate columns in series, with an effective length of 56 ft. In this set of columns the aqueous solution is contacted countercurrently with hexone, which extracts the columbium and tantalum, leaving the impurities behind. The aqueous solution leaving the column is discarded to a lime neutralization pit.

The solvent from the extraction unit is pumped to the center of unit 2—the separation unit—which is a series of five pulse-plate columns with an effective length of 144 ft. In the upper portion of this unit the solvent containing the columbium and tantalum is contacted countercurrently with demineralized water. This water dilutes the free acid in the solvent, effecting the transfer of all the columbium and a small amount of tantalum to the aqueous phase. The solvent leaving the top of this unit is pure in tantalum.

As the aqueous solution flows down through the lower portion of this unit, it is contacted countercurrently with purified hexone, which is pumped in at the bottom to remove any tantalum transferred along with the columbium. The aqueous raffinate going to the storage tanks is pure in columbium, and contains 0.8 to 1.0 lb of Cb_2O_5 per gal.

The solvent from unit 2 is contacted countercurrently with demineralized water in unit 3, comprised of two open columns with an effective length of 40 ft. The tantalum is transferred to the aqueous phase, and ends up in the tantalum raffinate storage tanks at a concentration of 0.08 to 0.1 lb per gal of Ta_2O_5. The solvent from unit 3 is purified by steam distillation and recycled through the system.

Table V. Typical Analyses of Columbium and Tantalum Oxides

Metal Impurity	ppm in Columbium Oxide	ppm in Tantalum Oxide
Al	20	<20
B	<1	<1
Cd	<5	<5
Co	<20	<20
Cr	<20	<20
Cu	<40	<40
Fe	<300	<100
Mg	<20	<20
Mn	<20	<20
Mo	<20	<20
Ni	50	50
Pb	<20	<20
Si	100	100
Sn	<20	<20
Ta	<300	
Cb		<300
Ti	<150	<150
V	<20	<20
W	<100	<100
Zn	<20	<20
Zr	<500	<500
Hf	ND	ND
F	600	600
LOI	0.06 pct	0.06 pct

The columbium and tantalum oxides are precipitated from the respective raffinates with 28 pct ammonium hydroxide. Both hydrates are filtered, repulped, washed with demineralized water, and filtered again. The slurry cake is pumped to the refractory-lined calciners and converted to the respective columbium or tantalum oxides.

Table V shows a typical analysis of the columbium and tantalum oxide produced by the Wah Chang Corp. separation plant. This is a spectrographic analysis and the impurities are shown as parts-per-million. The greatest impurity limitation in the whole process is the purity of the water used in the separation unit.

Oxides of the purity shown can be produced from any ratio of columbite or tantalite ore from 4:1 columbium to 4:1 tantalum. Small changes in the aqueous to solvent flow ratios are necessary to keep the system in balance. The total combined columbium-tantalum oxide content of the ore must be greater than 30 pct.

Conclusions

Liquid-liquid extraction is an excellent separation process flexible in both the type and the concentration of combined oxides in the ore used and in the oxide production rate through the system. The pure oxides produced are ideal for the conventional reduction process used to produce pure columbium and tantalum metals.

COOPERATIVE RESEARCH IN BRITAIN'S STEEL INDUSTRY

This is the story of BISRA, the British Iron and Steel Research Association. Written especially for the JOURNAL OF METALS, *this is the first in a series of articles describing major metallurgical research organizations in the US and abroad.*

by D. U. Hunt

Back in 1944, with the industrial war machine working at top pressure, Britain's steelmakers began to study the problems which would arise with the coming of peace. For years the short-term demands of the war effort had been paramount, but with victory in sight, the state of the industry in relation to a peace-time economy presented a great question mark.

Study culminated in two main policy decisions. First, a radical program for reorganization of the industry's resources—re-grouping, rationalization, closing certain works, and the planning other completely new integrated plants—the whole involving capital expenditure of hundreds of millions of pounds. The second policy decision involved extension of existing research facilities by the formation of a cooperative research organization working for industry as a whole. (Formerly, most research had been carried out by individual firms, although some rather uncoordinated, cooperative research had been going on since 1918).

The implementation of the first of these decisions is a matter of history, and is outside the scope of this article. It is with the implementation of the second—the formation, history, and achievements of the *British Iron and Steel Research Association* (BISRA)—that the writer proposes to concern himself.

Organization

The basic machinery for forming a cooperative research association already existed under the Government-sponsored Trade Research Association movement, organized by the Department of Scientific and Industrial Research (DSIR). This body, part of the British Civil Service machine, was formed to encourage such a movement as long ago as 1917. The DSIR has since initiated and fostered the growth of more than 40 similar research organizations for a wide variety of British industries. The Department's policy is to encourage the industry concerned to work out the necessary organization, with the Department contributing an annual *token* grant towards the running costs. General control of the activities of any such research association remains vested in the industry concerned, but the small financial grant by the Government provides some means of control, and a limited authority over its activities.

BISRA was, therefore, organized in association with the DSIR and the British Iron and Steel Federation (BISF), the *trade association* of the British steel industry. The greater part of BISRA's income, currently running at nearly one million pounds annually, comes from the Federation, which raises its income from a levy on the ingot tonnage produced each year. On this basis, all those companies which are members of the Federation, become *ipso facto* members of BISRA; in fact, this represents nearly 100 pct of all the firms engaged in the British steel industry.

To this main source of BISRA's income should be added the small annual grant from the DSIR and certain fees from patent rights, associate membership fees, and similar sources.

There are two main classes of BISRA members—*ordinary* and *associate*. Ordinary members are normally member firms of the Federation, while associate members are drawn from firms in allied industries interested in the work of the Association. These are, for the most part, suppliers of equipment or raw materials, or are users of steel. Commonwealth firms are eligible for membership, but foreign firms are excluded. Ordinary members, because of their Federation contribution, do not pay an individual subscription to BISRA, but associate members contribute according to their size and the extent of their interest in BISRA's work. Each member firm appoints an *official representative* who acts as a channel of communication between the Association and the firm.

The governing body of the Association is its *Council*. The British Iron and Steel Federation appoints 21 Council members; the Iron and Steel Institute, 9; and the DSIR and Iron and Steel Board one each. Up to five people may be co-opted for any one year. The Council, which is ultimately responsible for everything done by the Association, appoints from its members a Finance Committee and

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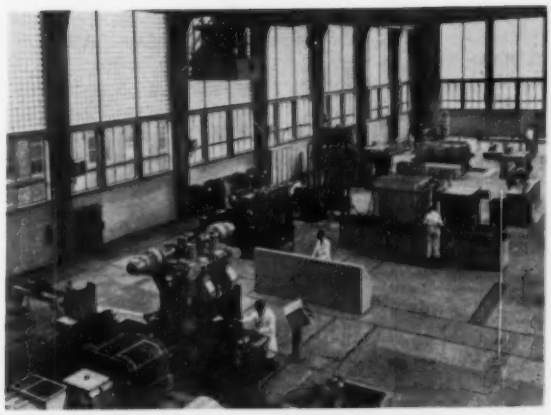
Operating BISRA's Ferranti 'Pegasus' computer at the Battersea (London) Laboratories.



The metal-working shop at BISRA's Sheffield (Yorkshire) Laboratories.

a Patents Committee. The Council delegates the supervision of the research program to *divisional panels*, and the executive action to the *Director* and his staff.

BISRA's responsibility for cooperative research begins with the iron ore in the ground, its preparation, and the processes required to make the ore into iron. It continues with the refining of the iron into steel, its shaping, treatment, and finishing. The properties of steel, the operation of plant and equipment, and the use of raw materials are also included.

Divisions and Departments

The Association is organized into five divisions, broadly corresponding to the natural structure of the industry. The *Ironmaking Division* covers iron production from ore mining to the delivery of the hot metal or cold pig iron. The *Steelmaking Division* studies the refining processes by which the many grades and types of steel are produced. The *Mechanical Working Division* is concerned with all the forming processes to which the steel ingot is subjected, together with research into organic and inorganic coatings on steel, and methods of surface treatment.

The manufacture of iron and steel involves the use of plant, machinery, and transport, together with power supplies—all on a huge scale; BISRA's *Plant Engineering and Energy Division* is responsible for studying these. The *Metallurgy Division* is concerned with all the physical, mechanical, and chemical properties of iron and steel, and the effect upon the properties of these variables in the manufacturing process.

In addition to the divisions, there are three departments which carry out fundamental research in support of the technological work done by the divisions. The *Chemistry Department* is responsible for research on slags, refractories, the corrosion of iron and steel, and the physical chemistry of steels. The *Physics Department* carries out research on metal physics, fluid dynamics, and instruments, and has recently formed a new section to study the application of automation to many aspects of production. The *Operational Research Department* is concerned with applying scientific techniques to assess the operational factors in the use of materials and machines . . . the human factors involved in improving working conditions and safety . . . and the use of computers in the steelworks, thereby assisting management in making decisions.

Laboratories

While this basic pattern was agreed upon early in the Association's life, its translation into fact was necessarily spread over several years. One important early decision was the location of the laboratories. After much deliberation, it was decided to place some of them in areas traditionally associated with specific aspects of iron and steel production, and others more centrally in London.

Consequently, the Ironmaking Division has laboratories and workshops at Normanby, near Middlesbrough, in the ironmaking area on Britain's northeast coast. That section of the Mechanical Working Division concerned with the surface coatings of steel sheet is housed near Swansea, in South Wales—the heart of the tinplate production region. Since Sheffield is the center for the production of special steels, early establishment of the Steelmaking and Metallurgy Divisions and the rest of the Mechanical Working Division was made here. Today, as a result of a large-scale rebuilding program, Sheffield's group of laboratories occupies a completely new set of buildings specifically designed for the Association's needs.

In London there are two sets of laboratories. The Blast Furnace Laboratory of the Ironmaking Division leased a small part of Imperial College of Science and Technology in Kensington. Here fundamental work is carried out before transfer to Normanby and pilot-plant-scale trials. The close association with Imperial College is of considerable advantage to BISRA, giving the opportunity for liaison with scientific experts in related fields of activity.

A much larger group of laboratories at Battersea, London—now being extensively rebuilt—houses the Plant Engineering Division and the three Departments. Finally, BISRA's headquarters and administrative machinery has offices in London's Park Lane. Altogether, the entire staff numbers around 560, 300 of whom are scientists and engineers.

This policy of locating laboratories in the center of the various production areas has been of great advantage both to BISRA and the industry. Research workers have opportunities for studying actual production conditions and can discuss topics of mutual interest with production men. Furthermore, arrangements can quickly be made for pilot-plant trials in actual works. Close relationships of

this kind give both parties insight into each others' problems, and avoids the *ivory tower* mentality which is an occupational risk of people engaged in research.

Research philosophy

At this point it would be helpful to crystallize the main philosophy behind the Association's work. BISRA's policy has always been to encourage the most intimate and direct relationship with the firms in its parent industry. It regards itself as *a part of*, not *apart from*, the industry. The cooperation of various firms in making works trials possible and in giving BISRA's staff advice and information out of *shop floor* experience is of the greatest value in giving practical character to BISRA's thinking.

As was stated earlier, a considerable volume of research is carried out by the larger British steelmakers; this, however, is necessarily concerned with the manufacturing interests of the companies concerned. There remains, therefore, a very wide variety of problems of a long-term, general character, whose solution is economically unattractive to any individual company. But this is just the sort of problem which is vital to the industry as a whole, and it was, in fact, to fill this important sector in the research front that BISRA was formed.

The problems which the Association studies are largely suggested by the industry itself through its nominated representatives on the BISRA Committees responsible for the research program. The men in the laboratories prepare interim and final reports on the work, which are, in turn, circulated to all members. BISRA makes every effort to have the results applied in practice, but the decision to do so is entirely that of the companies themselves.

Some achievements

In discussing BISRA's achievements over the 15 years of the Association's corporate existence, it is only possible to make an arbitrary selection, in view of the extremely wide field of activities involved. Most research workers will agree that the process of research is largely a succession of small advances, often interacting with each other and stimulating advances in parallel fields—rather than a few sensational jumps of the type familiar to readers of science fiction.

This point is clearly exemplified by the work of the Ironmaking Division. Investigations into the making and use of sinter have been continuing for many years, and the gradual adoption of new techniques, processes, and equipment arising out of these studies have helped to bring about a marked change in British sinter production and consumption over the past decade. In 1945, for example, British ironmakers were using 723.5 lb of sinter in the making of each long ton of pig; by 1958 this proportion was as high as 1598.2 lb, and while the production of pig iron has risen from 7,107,400 long tons in 1945 to 12,974,500 in 1958, sinter consumption over the same period has more than quadrupled—from 2,297,000 to 9,259,600 long tons.

In steelmaking, there has been a marked change over the past decade in the operation and control of the open-hearth furnace, still the dominant steelmaking unit in Britain. The traditional skill of the British steelworks operative has been reinforced by the introduction of a wide variety of control and recording apparatus, so that what was once a craft is now much more of an exact science. Laboratory studies in design have contributed to a marked increase in capacity and efficiency: where, in 1939, open hearths with a capacity over 80 tons were in a minority, capacities of 150 tons are now commonplace, and many furnaces are in the 200 to 300 ton bracket. An open-hearth furnace oil burner which reduces fuel consumption and increases furnace life was designed by BISRA, and is now widely used both in the UK and abroad. The efficiency of the electric arc furnace has also been considerably improved . . . hot topping practice has been developed so that ingot yield has been noticeably increased . . . and BISRA's work on continuous casting, especially in connection with special steels, has been widely acknowledged.

Currently, much work is being done on such problems as the direct reduction process, improved steelmaking techniques (such as vacuum melting and the use of oxygen) and, in particular, the question of applying automation techniques to many aspects of production.

Research into the working and fabrication of ingot products has led to a number of advances. Automatic gage control of sheet and strip by the BISRA roll force meter system is now widely adopted—not only in Britain but also in the US. The Association's work on wire drawing has materially contributed to higher and more economic production; the development of forge mechanization and automation now in an advanced stage should, when introduced, substantially raise efficiency in this section of the industry.

A BISRA project of some importance is the development of a PVC/steel laminate now in production under license from the Association. This product was developed in order to use materials and adhesives available in the UK. A laminating process was evolved in the Swansea Laboratories and was found in some respects to be superior to those produced by existing processes. The plastic skin is so firmly bonded to the metal that it cannot be peeled off without breaking the film. The laminate can be immersed in boiling water for 1 hr or more without failure of adhesion and can even be immersed in glycerine at 200°C for a few minutes without failing. Its wide applicability as a cladding and finishing material should provide an important new market for the British steel industry.

New instruments and apparatus

One could list a formidable range of new instruments and apparatus developed by the Association for the service of its parent industry, but space must preclude mention of more than a handful. One of the latest is an optical device for checking the dimensions of hot rod or bar moving at high speed, with another version adapted for measuring large forgings. Others include periscopes for studying conditions inside the open-hearth furnace, tinplate lamination detectors, and pyrometers—this is an arbitrary selection. Currently, work is proceeding on several projects, including a non-contact, nonmagnetic method of strip speed measurement, and an automatic inspection device for detecting surface defects on billets.

One of BISRA's most important developments has been in the field of data recording and information handling. Efficient cost and production planning demands continuous recording of plant operation, but conventional methods of recording (using charts and/or punched-tape systems) have the dis-

advantage that subsequent analysis is tedious and expensive in labor. The Association's Plant Engineering Division consequently devised a *performance recorder* for recording and subsequent analysis, presenting the results in tabular form, viz, punched tape from standard teleprinter apparatus. Each operator on a production line has a *push-button* station on which he can record running time and item time (distinguishing between *chargeable* and *non-chargeable*, and subcategories such as mechanical faults, electrical faults, and operational defects), order number, and shift number. The central *memory* store has a queueing device to accommodate simultaneous signals from several recording points, and the periodic accumulation of data on tape can be fed into and transcribed by teleprinter equipment as and when needed.

This system has been installed in at least one British steelworks and in several other industries. But it has recently been taken a step further by the introduction of what has been christened the *Tallimarker* system. This provides a much more efficient method of handling the flow of essential information in a steelworks—largely achieved at present by a combination of *word-of-mouth* and paper chits. The Tallimarker system has three basic units —a push-button station for each item of plant or machinery . . . a display screen before each operator in the production line . . . and an electrical *store*. Such an installation in a steelworks would mean that operators at the soaking pits, primary mill, primary shears, section mill, and saw bench would all have push-button consoles, and all points after the soaking pits would be equipped with a display screen showing the *history* of the ingot as it was progressively reduced. As the product passes down the line, each operator reads off the facts on the screen, carries out his particular job, and records the facts for the benefit of the next man. When a section reaches the final saw, the store would hold its complete history. Details would be relayed to the mill office and recorded on, say, a punched card, or punched or magnetic tape.

The system as outlined can, of course, be adapted for almost any production scheme. It reduces clerical work, and can save both time and money, while the hardware concerned is largely standard material, with relatively simple circuitry.

Application of research

From the beginning, the Association has always been aware that the value of research to the steelmaking community is proportional to its degree of application. BISRA's *Development and Information Service* is responsible for making known the results of research and for encouraging its application. Through the Information Service, members are kept up-to-date with progress of BISRA's research program by published lists of research reports and by BISRA Summaries. These Summaries are aimed at management and operating personnel rather than scientists and engineers, and give brief, simplified accounts of projects reaching an advanced stage. They are intended to arouse industry's interest in work ready to be applied. All this information is, of course, primarily intended for the benefit of member companies; however, after some time has elapsed, it is generally made available to anyone interested, and, where suitable, released to the technical press.

New and improved processes and equipment developed in BISRA are patented, and the Development Section supervises their exploitation and grants licenses to interested manufacturers. In addition to the Information Department, a number of service facilities have been progressively introduced. A *bank* of pedigree irons and steels of known provenance is held at the Sheffield laboratories, freely available to other research workers in the various companies and elsewhere.

A *Corrosion Advice Bureau* was formed in 1954 to make the experience of the Corrosion Section more generally available and in the same year a *Steel User Service* was instituted. This gives British manufacturers and users of steel direct contact with the latest technological developments, not only of BISRA but of the whole of the industry, and its rapid expansion has shown quite clearly that it serves a very valuable purpose. These services are essentially practical and down-to-earth; a manufacturer can check on the best grade of steel for a particular purpose . . . can ask for an expert to visit his work for a trouble-shooting session . . . or can arrange for laboratory tests to be caried out.

Latest extension to this advisory build-up is an *Operational Advisory Service*. Operated by the Operational Research Department, it seeks to supplement managerial experience by scientific forecasts of the probable effects of different policies. Steel firms can ask for an investigation into such questions as the most efficient and economic stock-level program, or problems involving internal transport, or delivery arrangements—road vs rail, diesel vs. steam or electric movers, for example.

Another section of the Operational Research Department is concerned with computer applications. A digital electronic computer was acquired two years ago and a special section was formed to study possible applications of computer techniques—not so much as a research tool but as an administrative or production aid. In conjunction with member firms, several such applications have, in fact, been worked out. Furthermore, the Department runs a series of classes in the use of computers for steel firms' staff, and holds periodic symposia and conferences for member-companies' men to study possibilities and operating techniques. The computer is also available to members on a hiring basis.

Appraisal of BISRA

After 15 years, BISRA is now inextricably part of Britain's steel industry. It is an essential element of that industry, working with it and for it. The pattern evolved in 1944 has proved, by experience, to be basically sound and to have rendered good service. But those responsible for its direction and development are sensitive to that tendency towards ossification which sometimes accompanies maturity. The organization is, therefore, kept as flexible as possible, so that resources can swiftly be adapted to meet changing demands. The intimate ties with the industry which are the very essence of BISRA are a further assurance that this policy will be maintained.

The British Iron and Steel Research Association is not an academic body working in a vacuum . . . it is not a creature of the government of the day . . . it is, simply, an essential part of a thriving, progressive industry.

Symposium on Electron Beam Processes

by Robert Bakish

The second Alloyd Corporation Symposium on Electron Beam Processes was held on March 24th and 25th at the Sheraton Plaza Hotel in Boston. The ever-increasing interest in electron beam processes is attested by the fact that whereas last year's attendance was 60, this year over 200 participants—representing a good fraction of US industry from coast to coast—were on hand for the presentation. Thirteen papers covering most electron beam applications and a panel discussion on electron beam welding made up the meeting program.

Introductory remarks by J. Hetherington opened the Symposium and pointed to some interesting and early Pirani electron beam patents in the field. W. Glenn of the General Electric Co. was the first of the invited speakers, presenting a paper entitled *Thermoelastic Image Formation*. This work described the newly-developed electron beam process for image formation. The process utilizes a scanned beam of electrons incident on a thermoplastic film to lay down a modulated charge pattern on the surface. This surface is then heated to the plastic flow temperature of the film, allowing the charged pattern to deform the surface, which is then allowed to freeze. When illuminated by a schliern optical system, an image is created by the surface deformations. A standard 16 mm-wide film is used, but the actual track is only 5 mm wide. Possibilities of further track size reduction without loss of resolution are at hand. Ten inches per sec is the usual recording velocity. The recording technique is immediately applicable to television, and could have innumerable applications in the field of electronics. Dr. Glenn presented several short strips of this recording to illustrate the quality of the image.

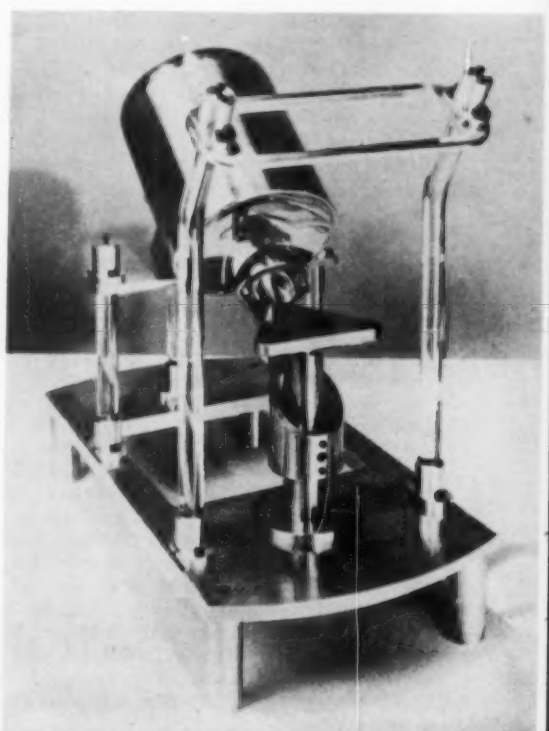
H. Smith of the Temescal Corp. was the second speaker, and the topic of his talk was *The Economics of Large Scale Drip Melting*. After briefly presenting the present state of the art of drip melting and the power levels (250 kw) of today's largest electron beam furnaces, Dr. Smith proceeded with a discussion of the economic aspects of scaling-up such furnaces to 1500 kw. It is expected that this scale-up will bring electron beam melting in a much more favorable economic position. Insight into electron beam melting problems and experience with different materials was presented.

The applications of electron beam machining were discussed by M. Rider of L-R Industries in *A Commercial Electron Beam Machining Facility*. He related the performance and capabilities of the only electron beam machining unit in the US. The operational details of the machine were discussed and a motion picture of actual machining operation was presented. Applications of the equipment in the textile field for preparation of spinarets and in the electronic industry for special microminiaturization tasks were presented.

Dr. Opits from Carl Zeiss Corporation followed with a presentation entitled *Laboratory Developments in Electron Beam Machining*. Electron beam machining techniques presently being developed on a laboratory scale were discussed. The discussion was capably amplified by presentation of the theory of the process and specific design details and functions of the equipment.

The next paper, presented by R. Bakish, discussed the Alloyd Corp.'s work in the field. A modular approach device utilizing electron beams for melting, evaporating, welding, zone refining and plain heating has been developed. The miscellaneous modules and their design features were discussed, as were their working results. The Alloyd Corp. also took the occasion to announce that it will commercially produce electron beam evaporators.

R. Connor of High Voltage Engineering Corp. presented the sixth paper, *Properties of Electron Beams at High Voltage and Power Levels*. Here, data on electron beams with energies up to 10mv and power levels of several killowatts was presented. This data was followed by a discussion of the applications of these high voltage beams to the chemical



Electron beam gun for ultra-high vacuum evaporation (IBM Laboratories).

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and food-processing industries. Information on beam behavior after impingement through windows into the air . . . and data on depth of penetration into metals, radiation hazards, and other matters of general interest completed the presentation.

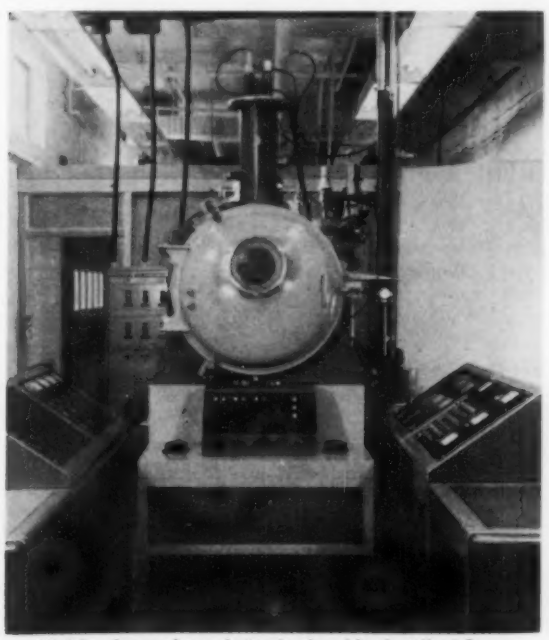
The next paper, by Dr. Hayashi from the Japan Vacuum Engineering Co. presented a most novel furnace for the sintering of tantalum pellets for the capacitor industry, utilizing electron beams as a heat source. Experimental data on pellets prepared in this furnace indicate some interesting possibilities for electron beam heating for this application.

The problem of *The X-ray Hazards in Electron Beam Processes* was competently discussed by F. Masse of the Radiology Safety Group at Massachusetts Institute of Technology. He pointed out that the high voltages encountered in some electron beam equipment are a more obvious and immediate danger than the more insidious exposure to radiation. He then proceeded to point out the sources of X-rays, and presented information on shielding requirements and monitoring procedures.

One of the newest techniques of thin film evaporation is the use of an electron beam for a heat source, rather than resistance heating. The electron beam is particularly applicable to the heating of metals and dielectrics, which have high melting temperatures and tendencies to react with the heating elements. Dr. Thun of International Business Machines Laboratories discussed the design of electron guns for this purpose in his paper.

The last paper on the general application of electron beam processes was presented by M. G. Selvin of the Sylvania Microelectronics Laboratory. His topic: *The Future of Electron Beam Techniques in Microelectronic Circuitry*. After outlining the problems that confront those developing microelectronic devices, Mr. Selvin described some pertinent design characteristics that electron beam equipment must have to be successful in this field.

The main theme of the Symposium's second day was electron beam welding. The sessions were started with a paper by Mr. Tessmann of National Electrona, Inc., entitled *Laboratory Scale Performance of a High Voltage* (100kv) *Electron Beam Welder*. Mr. Tessmann, who operates this welder on a job shop basis, described in great detail the design and operation of the unit and then proceeded to show photomicrographs of a variety of welds in order to demonstrate the capabilities of the apparatus. The high depth:width ratio of the weld was quite well demonstrated.



Modular electron beam device developed by the Alloyd Corp.

Mr. Hablanian of the NRC Equipment Corp. presented the alternative approach to electron beam welding, namely, low-voltage guns. The presentation was entitled *Laboratory Scale Performance of a low Voltage* (20kv) *Electron Beam Welder*. Here Mr. Hablanian discussed the virtues of low-voltage electron beam welding. Despite the lesser depth: width ratio achieved with low voltage, the high quality of welds produced still indicates a definite place for this device.

The welding session was completed by a most timely and indeed illuminating panel discussion on electron beam welding. This panel was capably led by Mr. Hartbower from the Watertown Arsenal Laboratories. His panel consisted of E. Franco-Ferreira, Oak Ridge National Laboratories; H. Kalish, Olin Mathieson Laboratories; L. E. Stark, Mallory Sharon Co., W. N. Platte, Westinghouse Electric Corp.; and Mr. Niedzieski from Airco Co. Mr. Platte, who has had considerable experience in welding refractory materials, attempted to point out the problem areas where the electron beam welding approach could be used successfully. He emphasized, however, that no welding technique had and neither electron beam welding would, modify the inherent properties of materials and that these will remain independent of techniques. Mr. Stark, experienced both in electron beam melting and welding, discussed the gas content in the weld material and the possibilities in electron beam welding of electron beam-melted materials. Mr. Kalish, whose laboratory has been engaged in high-voltage electron beam welding, discussed their experience. Mr. Niedzieski presented some of the practical aspects of low-voltage electron beam welders, such as operators, training stability, and reproducibility. Mr. Franco-Ferreira, who has been in charge of electron beam welding at Oak Ridge, discussed application of low-voltage equipment to special problems. He commented that the material to be welded really was insensitive to the potential of the electrons impinging upon it, and with sufficient power density he feels low voltage should achieve high penetration. These comments were followed by an extensive question and answer period. The general impression of the whole discussion was that the field of electron beam welding is indeed very young and a great deal of questions are yet to be answered.

With the completion of the panel discussion, L. McD. Schetky of the Alloyd Corp., and Symposium Moderator, thanked all participants and closed the meeting. All participants will be notified of the details on the Third Electron Beam Symposium to take place in the spring of 1961.

The proceedings of the Second Symposium on Electron Beam Processes will be available at $5 and should be off the press this month. Order copies through the Alloyd Corp., 35 Cambridge Parkway, Cambridge, Mass.

1960 AIME Annual Meeting (Cont)

Review of EMD Sessions

This is a continuation of the JOURNAL OF METAL'S *coverage of the technical sessions of the 1960 AIME Annual Meeting. In the May issue several of the important Iron and Steel Division sessions were reviewed, and next month it will be the Institute of Metals Division's turn . . . but this month the spotlight is on the Extractive Metallurgy Division. We wish to express our appreciation to K. A. Phillips of American Zinc, Lead & Smelting Co. and to J. A. Leary of Los Alamos Scientific Laboratory for preparing these reviews.*

International Symposium on the Extractive Metallurgy of Copper, Nickel, and Cobalt

Reviewed by K. A. Phillips, American Zinc, Lead & Smelting Co.

Fluid-Bed Roasting—Principles and Practice, by R. B. Thompson, Dorr-Oliver Inc., and G. Roesner, Lurgi Gesellschaft.

The authors gave a clear picture of the basic roaster types now in commercial operation, relating gas velocities and bed characteristics by the use of Schytil's phase diagram of gas-solid suspensions. With a very coarse feed, most of the ore burns within the bed and reports in the overflow. Where a high steam efficiency is desired the bed is cooled internally. A very high output per unit of cross-section is possible with such a feed.

When the feed is one of the coarser flotation concentrates, most of the ore burns within or just above the bed, but over half of the calcine may be collected by the cyclones. Particles of marginal size may be incompletely roasted when they leave the roaster. Some of these can be returned to the roaster if a total calcine very low in sulfide sulfur is required.

If the feed consists of very fine concentrates as at the new Inco iron plant, the roaster may use a *flying bed.* Little or none of the product actually overflows, and a substantial percentage of the coarser cyclone product is recirculated to control temperature and to promote a low sulfur assay in the final calcine.

Cobalt-Nickel Separation Through Volatilization of Certain Organic Compounds, by P. G. Grimes, Allis-Chalmers Research Laboratories.

Mr. Grimes showed that copper and nickel can be separated by the selective volatilization of certain organic compounds. The efficiency of separation is excellent, but the operating cost might be rather high. Losses of the organic compounds used must be minimized by methods of recovery and recycling which may not be economical at this time.

Cobalt-Nickel Separation by Solvent Extraction, by J. E. Magner, Dow Chemical Co.

Cobalt and nickel can also be separated almost perfectly by solvent extraction. Mr. Magner presented a complete and metallurgically feasible flowsheet for the operation, although the separated nickel and cobalt solutions are rather dilute for the most economical recovery of the two metals. It is possible that the initial solutions can be reconcentrated by ion-exchange or solvent extraction methods.

Smelting Practice at Noranda and Gaspe, by J. N. Anderson, Noranda Mines, Ltd.

Mr. Anderson presented an unusually complete paper, supported by many slides taken at the Noranda and Gaspe smelters. Although Noranda has set many fine records in the smelting of hot calcines, the newest reverberatory furnace receives wet concentrates. The charging tubes are served by shuttle conveyors, and each tube has a shut-off gate near the arch. The monthly tonnage is about the same as for the two older furnaces, but the matte from the new furnace contains about twice as much total copper and silver. The fuel consumption is about 75 pct higher for wet charging, so that the total direct operating cost is 7 to 10 pct higher per ton of ore. However, the new furnace is much cleaner to operate, and the extra operating cost is balanced by lower losses of copper in slag and dust.

Converter efficiency has been raised very substantially by the use of more and better-controlled air and by improvements in flux handling. Tuyeres are punched mechanically, and metered air is supplied to yield a definite cyclic temperature pattern, recorded by a radiation pyrometer mounted on the hood. Visual control is no longer employed. The flux is closely sized, blended to give a silica content between 66 and 68 pct, and weighed before charging with the Garr guns. The Gaspe converters do not employ mechanical tuyere punching, but efficient design of the plant keeps them on the line 77 pct of the possible time. A 12-hr cycle is used, and white metal is kept within the specified temperature limits by the addition of cold blister copper blocks.

Smelting Practices of Phelps Dodge in Arizona, by M. G. Fowler, Phelps Dodge Corp.

Mr. Fowler's printed paper contains 52 pages of valuable data concerning the Phelps Dodge smelters at Morenci, Ajo, and Douglas. His oral presentation covered such interesting topics as the history and modern use of bath smelting, the reduction of copper with reformed natural gas in a modified converter, and the hot patching of silica arches.

The No. 9 reverberatory furnace has a deep bath, and it treats the finer and richer ores available at Ajo. The advantages gained are: better control of magnetite, greater capacity because of the unobstructed furnace cross-section, decreased dust losses, cleaner slags, and economies in converter operation due to the surge storage of matte.

The use of reformed gas in fire refining has eliminated the need for poling. Discussion of this operation led to questions concerning the use of oxygen in standard converters. It is used in a Japanese furnace for the direct converting of pelletized concentrates, but the general use of oxygen is rendered difficult because converters are not blowing during 20 pct to 30 pct of each cycle. The economic recovery of waste heat is rendered difficult for the same reason.

Certain Limiting Factors in the Design and Operation of Pierce-Smith Converters, by W. J. de Villiers, R. C. Bohme, N. Gibson, and W. A. Kealy, Rhokana Corp., Ltd.

Converter practice at Rhokana is unusual in several respects. The reverberatory matte contains about 60 pct Cu, and sulfuric acid is produced from the converter gases. Very careful attention to the supply and use of blast air has permitted a 119 pct increase in converter capacity since 1952. The printed paper describes the air distribution and control systems in detail.

Converter Practice at Chino Mines div., Kennecott Copper Corp., by M. K. Nicholson, P. L. Lockridge, and G. C. Beals, Kennecott Copper Corp.

The authors described the operations at Hurley and showed how greater converter efficiency and capacity has been achieved by increasing the blowing rate, the percentage of stack time, and through instrumentation. A new type of tuyere puncher was developed to meet the specific needs of the Chino div., and the refractories in the tuyere area have been rearranged to minimize damage to the brickwork. Stainless steel tuyere pipes protect the refractories, and these pipes are much easier to ream.

This year the converter instrumentation is to be completely overhauled to provide automatic punching, manually variable blast pressure, remote control positioning, and the recording of stack time. Three men will operate two converters.

Electric Smelting of Sulfide Ores, by Otto Barth, Barths Metallurgiska Byra.

Dr. Barth discussed the electric smelting of sulfide ores in Europe and Africa, and referred briefly to the interesting lead operation at Boliden. Advantages in magnetite handling and dust control are generally achieved, but slags are seldom as clean as those from American reverberatory furnaces.

Utilization of Nickeliferous Serpentine, by L. H. Banning, US Bureau of Mines.

The process developed by the US Bureau of Mines is also suitable for the treatment of nickel-bearing laterites, but it was developed specifically to permit the exploitation of the nickeliferous serpentines associated with most of the richer laterite deposits. Wet methods employing a basic extractant can be applied with fair success to some serpentines, but an acid leach always extracts a prohibitive amount of magnesium from serpentine.

In a small electric furnace (with a diameter of 45 in. inside the refractory lining) ores from the Philippines and western US have been smelted at a high temperature to yield ferro-nickel containing 18 to 26 pct Ni and 0.4 to 0.8 pct Co. No flux is used; the charge consists of calcined serpentine, coke, and enough bagasse to control the bulk density and porosity of the mixture. Nickel recoveries of over 90 pct have been achieved with power consumptions of 760 to 1200 kw-hr per ton of ore (23 to 32 kw-hr per lb of recovered nickel.

At present prices, the extraction of nickel from serpentine is probably uneconomic, and the Ugine process is more attractive for related ores somewhat richer in iron and nickel.

Leaching and Electrowinning of Copper from Nchanga Oxide Concentrate, by F. H. Chapman, Anglo American Corp. of South Africa, Ltd., and E. W. Page, Nchanga Consolidated Copper Mines Ltd.

The concentrator receives 360,000 tons of ore per month, and it produces a sulfide concentrate for direct smelting, a small tonnage of primary oxide concentrate assaying 30 pct Cu, and about 50,000 tons of secondary oxide concentrate for the leaching plant. The crude ore averages 4.69 pct total copper; the secondary oxide concentrate contains about 13 pct Cu. There is an advantage of about 3¢ per lb in the treatment of the secondary concentrate by leaching and electrowinning, as compared with smelting and refining in a plant already suffering from a deficiency in sulfur.

Leaching with return electrolyte is carried out in three stages. The primary thickener overflow goes to the purification section, where the iron is oxidized with manganese ore and then precipitated with copper hydroxide scavenged from the solutions of the residue washing plant.

Tankhouse practice is reasonably conventional. The mastic lining inside the reinforced concrete cells has been replaced by lead, and the use of plastics for pipes, launders, and small tanks is expanding rapidly. The starting sheets are of copper, and the insoluble anodes are made of 6 pct antimonial lead. The evolution of acid mist is suppressed with a film of a light lubricating oil.

Leaching of Chuquicamata Oxide Copper Ores, by J. A. McArthur and Clark Leaphart, Chile Exploration Co.

The authors gave a well-illustrated description of a process that has been thoroughly time-tested. Current operations differ from those of the past in that the grade of the ore is decreasing, and it is very difficult to maintain an acid balance. Some dilute washes are therefore being wasted, and a contact acid plant is being built to supply 75 tpd of sulfuric acid.

The dechloridizing plant is of special interest, since four steps are carried out. The ferric iron in the strong solution is reduced with coarse cement copper, and cupric chloride is reduced to insoluble cuprous chloride at the same time. The latter compound is removed by settling and decantation, and it is redissolved in hot ferrous chloride solution. The dissolved copper is then precipitated out with scrap iron, regenerating the ferrous chloride solution for reuse. The coarse cement copper is returned to the head of the dechloridizing circuit, and the fine copper is used to strip the solutions to be wasted from the leaching plant and the tank house.

The continuous treatment of part of the return electrolyte in three sulfur dioxide absorption towers

reduces part of the ferrous iron and increases the acid content. More important, the adverse effects molybdenum and of decomposed nitric acid are avoided.

Factors in Choice of Corrosion-Resisting Materials for Refining Equipment, by F. L. LaQue and C. M. Schillmoller, The International Nickel Co.

The authors presented a clear picture of the corrosion problems encountered in the handling of acidic sulfate solutions, many of which contain copper. The effects of aeration and of various dissolved salts upon the performance of typical construction materials were covered swiftly and skillfully. Graphs illustrated key points, such as the effect of temperature.

The following papers of this symposium were published in the March issue of JOURNAL OF METALS: **Treatment of Copper Nickel Matte for Metals Separation and Recovery** by Kelvin Sproule, The International Nickel Co., G. A. Harcourt and L. S. Renzoni, The International Nickel Co. of Canada, Ltd. (pp. 214-219), **Production of Ferronickel at Riddle, Oregon** by E. E. Coleman, Hanna Nickel Smelting Co. and D. N. Vedensky, Hanna Mining Co. (pp. 197-201), **Ferro-Nickel Smelter of Doniambo (New Caledonia)** by C. G. Thurneyssen, J. Szeczeniowski, and F. H. Michel, Societe le Nickel (pp. 202-205), and **Pressure Leaching of Nickeliferous Laterite with Sulfuric Acid,** by E. T. Carlson and C. S. Simons, Freeport Nickel Co. (pp. 206-213).

Electrolytic Processes

A Basket-Cathode Electrolytic Cell for the Production of Titanium Metal, by W. R. Opie and O. W. Moles, Titanium div., National Lead Co.

The evolution of the basket cathode opens the door to the development of a commercial process, with the potential of decreasing the cost of making titanium sponge by eliminating the need for an intermediate reducing metal such as sodium or magnesium. Materials of cell construction are inexpensive—graphite, steel, acid-resistant brick, and small quantities of nickel and Inconel. Having eliminated diaphragms and semi-walls, the cell is very simple and should have a long life. Because the titanium values are confined to the basket interior, there is no reaction of reduced chlorides of titanium with the brickwork. Current-voltage characteristics are such that multiple cathode cells can be connected in series, similar to conventional electrolytic copper or zinc installations.

The following papers, presented at this session, will be published in future issues of the JOURNAL OF METALS: **High-Purity Electrolytic Chromium,** by M. J. Ferrante, P. C. Good, F. E. Block, and D. H. Yee (US Bureau of Mines) and **Factors in the Electrowinning of Higher Purity Ingot Cerium from Molten Salts,** by B. Porter, E. S. Shedd, C. Wyche, J. D. Marchant, and R. G. Knickerbocker (US Bureau of Mines).

Nuclear Fuel Reprocessing

Reviewed by J. A. Leary, Los Alamos Scientific Laboratory

Purification of Irradiated Nuclear Fuels by Crystallization from Liquid Metal Solvents, by S. Lawroski and H. M. Feder, Argonne National Laboratory.

The purification of an impure metal may sometimes be accomplished by crystallizing it from a suitable liquid metal solvent. The factors which limit the purifications achievable are: 1) entrapment of the mother liquor; 2) co-precipitation (i.e., distribution of an impurity between crystals and solution); 3) incomplete physical separation of crystals and mother liquor; and 4) contamination of the product by materials of construction, etc. These factors were discussed as they pertain to the problem of purifying irradiated nuclear fuels for the purpose of removing fission product elements or recovering variable fissile elements. Illustrative data (e.g., solubilities, coprecipitation behavior, filtration characteristics) acquired for the purpose of designing a process for the decontamination of uranium blanket fuel by the use of zinc, cadmium, and magnesium as solvents were presented.

Use of Mercury in Reprocessing Nuclear Fuels, by O. C. Dean, A. F. Messing, and H. C. Forsberg, Oak Ridge National Laboratory.

Uranium, thorium, and plutonium form series of intermetallic compounds with mercury of low stability. Although these intermetallics are quite pyrophoric, they are wetted and protected from oxidative atmospheres by excess mercury. The uranium-mercury compound UHg_n, which is stable at 1 atm at temperatures below 365°C, is soluble in mercury up to 1.2 atomic pct U at 365°C. The plutonium compound is nearly as soluble, but $ThHg_n$ is about one order less soluble. Since the noble fission products, e.g., ruthenium and molybdenum, have mercury solubilities from two to five orders less than uranium, good separations may be obtained. The more soluble alkaline earths and rare earths are oxidized preferentially and their oxides are not wetted by mercury, so they can be filtered from the hot uranium solution.

Uranium and thorium are readily recovered from mercury. The mercurides crystallize and can be filtered from solution at 25°C. Vacuum distillation at 800°C removes the remaining mercury to < 10 ppm. The uranium may be melted in the same retort; thorium appears as massive, but porous, sintered billet with a density of ~ 75 pct of theoretical.

Experiments in Pyrometallurgical Processing of Thorium-Uranium Fuels, by G. E. Brand, E. W. Murbach, F. W. Dodge, and W. N. Hansen, Atomics International.

Results of studies carried out at Atomics International indicate that pyrometallurgical methods offer promise for reprocessing thorium-uranium reactor fuels. Methods under investigation include direct volatilization, molten salt electrolysis, and molten magnesium extraction. The results of these experiments have shown fission product removals of from 50 to 95 pct.

The Aluminum Magnesium Pyrometallurgical Process for Spent Uranium Nuclear Reactor Fuels, by Robert J. Teitel, Dow Chemical Co.

A pyrometallurgical process employing molten aluminum as a solvent and magnesium as a precipitating agent has been studied. The process consists of four major steps: 1) dissolution of uranium in aluminum; 2) precipitation of uranium intermetallic compound; 3) dissociation of uranium compounds; and 4) recovery of metallic uranium.

Light Metals

Reviewed by K. A. Phillips, American Zinc, Lead & Smelting Co.

Production of Beryllium Metal of Nuclear Purity, by C. W. Schwenzfeier, The Brush Beryllium Co.

In an interesting, well-illustrated talk, the author listed the plants producing beryllium metal and master alloys, emphasizing the leadership of the US in this field. Although a very large English plant has been tentatively scheduled for construction, its actual output will probably be limited to copper-base alloys unless the UK AEA decides to use beryllium-clad fuel elements in its gas-cooled nuclear reactors.

The Brush Beryllium Co. melts the hand-cobbed beryl ore and then quenches it to render the complex silicate soluble in sulfuric acid. Aluminum dissolved with the beryllium is then separated out as ammonium alum. After further purification, beryllium is precipitated as the hydroxide, and the latter is calcined to the oxide.

Beryllium oxide is converted to the fluoride, which is then mixed with magnesium metal and charged into a graphite-lined furnace. The thermit-type reaction yields finely-divided beryllium metal and a slag composed of magnesium fluoride and excess beryllium fluoride. Further heating allows the coalescence of the metal into pebbles, which are later recovered and refined in vacuum arc furnaces. Careful workmanship has permited the production of metal which meets specifications more rigid than those originally developed by the US AEC.

The beryllium recoveries achieved from cobbed mineral to refined metal range from 80 to 86 pct.

Aqueous Electrolytic Processes and Related Operations

Reviewed by K. A. Phillips, American Zinc, Lead & Smelting Co.

Germanium in the Electrolytic Zinc Cell, by W. F. Zelezny, Phillips Petroleum Co., and J. H. Foreman, Anaconda Aluminum Co.

The importance of germanium as a minor impurity in the electrolytic zinc process has long been recognized, but not clearly evaluated. A relatively complete study of germanium effects on the electrolytic deposition of zinc was given by the authors, which includes the influence of germanium alone . . . in combination with other impurities . . . and in combination with additional agents. Lead anodes coated with lead dioxide was revealed to be a collector of germanium from the cell electrolyte, and evidence of germanium hydride evolution at the cathode was presented. In part, the reasons for conflicting information about the influence of germanium in the electrolytic zinc cell were pointed out.

Mechanical Casting of Slab Zinc, by R. K. Carpenter and P. M. Dampf, American Zinc Co.

The authors' description of the operation was illustrated by many colored slides, which showed in detail the equipment and the method of operation. The zinc cathodes are melted in a gas-fired reverberatory furnace, which is drossed once per shift. The molten zinc flows to an Ajax induction furnace, modified as a pneumatically-actuated pump for filling three molds at a time. The casting wheel is 14 ft in diam and carries 36 water-cooled molds. Solidified slabs are removed by a set of three lifters equipped with vacuum shoes.

A crew of five men operate and dross the furnace, cast 50 to 60 tons of metal at a rate of 10 ton per hour, and stack and store the slabs cast.

Iron from Pickle Liquors, by C. L. Mantell and L. G. Grenni, Newark College of Engineering.

The authors made a careful economic study of the recovery of ferrous sulfate and sulfuric acid from waste pickle liquors. The method used employed ion-exchange membranes, and the process is metallurgically feasible. It is not attractive economically because of the cost of maintaining and replacing the somewhat fragile diaphragms.

Reviewed by K. A. Phillips, American Zinc, Lead & Smelting Co.

New Developments in Extractive Metallurgy of Refractory Metals

Reviewed by K. A. Phillips, American Zinc, Lead & Smelting Co.

Fused Salt Electrorefining of Tungsten, by F. Cattoir, R. Cumings, and D. H. Baker, Jr., US Bureau of Mines.

The authors described recent pilot-scale work conducted by the Bureau of Mines. Either tungsten scrap or impure primary metal chips can be used as the source metal, and electrical current is supplied to them through the graphite cell liner. A tungsten wire is the most successful cathode used to date, and the fused electrolyte is largely borax. In order to obtain a deposit of the desired purity it is essential that the fused bath be electrolyzed for several days before the working cathode is inserted. The current employed is very low, and the cathode produced is a cluster of needle-like crystals. The removal of the adhering salts without the contamination of the crystals requires very careful workmanship.

Columbium—From Ore to Metal, by K. C. Li, Wah Chang Corp.

The production of a metal as new as columbium is usually cloaked in secrecy, so it was a pleasant surprise to have this interesting paper accompanied by slides showing almost every piece of equipment used in the process. The Wah Chang Corp. is developing the world's largest columbium deposit in Brazil, and the golden yellow crystals of pyrochlore found at Minas Gerais contain over 70 pct of Cb_2O_5. This mineral is dissolved in hydrofluoric acid and is purified by solvent extraction. About 70 pct of the columbium oxide is converted to the carbide, and the latter is reacted with the remaining columbium oxide to yield metal. The carbide-oxide briquets are reacted in an induction or resistance furnace at a temperature of 2050°C and at a finishing vacuum of less than 10 μ. The crude metal obtained is then purified by vacuum arc sintering and by a final melting in an electron beam furnace.

In this issue the JOURNAL OF METALS is publishing the article **Production of Pure Columbium and Tantalum Oxides by Liquid-Liquid Extraction** by C. W. Carlson and R. H. Nielsen, Wah Chang Corp.

Lead and Zinc Research

by Schrade F. Radtke of the American Zinc Institute & the Lead Industries Assn.

The lead and zinc industries of the US, Canada, England, Australia, South America, and Africa—through the Expanded Research Program of the American Zinc Institute and the Lead Industries Association—have undertaken a major research effort to develop new uses for lead and zinc, backed up by extensive fundamental research.

Although the program has been under way for only a few years, significant results have been achieved. Research at the Battelle Memorial Institute, devoted to new plating processes for automotive zinc die castings has shown that duplex nickel over conventional copper, followed by bright, crack-free chromium, results in a plating system far superior to conventional practices—which can no longer withstand the severe corrosive conditions encountered on today's highways. This new system has important applications for appliance and marine hardware, as shown by exposure tests.

A new titanium-copper zinc-base alloy has broad application for architectural markets. For lithographic plate, its resistance to creep and its adaptability to lithographic plate preparation promises recovery of zinc's former position. The Lithographic Technical Foundation has developed new graining and wipe-on diazo treatments for this alloy which will enhance zinc's technical merits.

A cooperative effort with the John F. Robertson Co. has led to the development of a new press for the continuous extrusion of lead cable sheathing alloys. For the first time, it has been possible to extrude continuously the arsenical alloys, tellurium-bearing lead, and antimonial lead. Heretofore, only commercially-pure and copper-bearing lead have been extruded continuously. Not only will cost reductions be possible in continuous extrusion, but a metallurgically superior product can be produced, and plastic insulating materials can be employed as well.

At Rutgers University a fundamental investigation of ceramic dielectric materials employing lead additives has resulted in the development of an ultra-low-loss dielectric material superior to anything known previously. This is only one of 11 fellowships covering the utilization of lead in ceramics, glasses, glazes, ferroelectrics, and thermal and spectral emissive materials. A corresponding program is being initiated for zinc.

The incorporation of galvanized steel in the underbody portions of unitized automobile bodies promises to yield a vital, new market for zinc. While significant advances have been made in resistance welding steel, satisfactory electrode life for mass production lines remains to be achieved. An important welding program has been started at The Budd Co. to assist in developing welding electrodes and welding practices to meet production line requirements.

The New Jersey Zinc Co. has under investigation new die casting alloys for the hot chamber process in the range of 5 to 18 pct Al. The principal objective is to achieve materials with superior physical properties and castability.

Rensselaer Polytechnic Institute is conducting fundamental investigation of the powder metallurgy process for producing wrought alloys directly from powders. Initial results have shown that superior properties can be obtained by naturally-occurring oxide films on the particles together with fine-grained material showing nondirectional properties. In the lead system, a 5 pct Cu alloy atomized and air-quenched has yielded ultimate tensile strengths in the range of 8000+ psi and elongations of over 15 pct.

Other dramatic property improvements, accompanied by significant increases in resistance to creep, have been obtained through the use of fiber mat reinforcement of lead. This research, together with a vital study of lead-base alloys, is being undertaken at Armour Research Foundation. This latter study, incorporating lead of 99.9999 pct purity, has caused a reassessment of prior literature. Alloying elements added in thousandths of a percent produce major changes in physical properties and point the way toward the development of improved lead alloys.

Because of lead's high density and low modulus, it has inherently excellent characteristics for attenuating sound and vibration. Composite pads of lead and asbestos have been used for years in attenuating vibrations from railroad beds in building structures, but complete engineering data required for exploitation of related markets were unavailable, hence the initiation of a major program to develop attenuation characteristics of lead as a function of frequency and unit loading.

In sound, lead incorporated in plastic sheeting has been used to attenuate sound in the DC-8 jet transport and other aircraft. The potential for architectural applications in sound-impervious drapes, building partitions, doors, and wallpaper is great, hence the initiation of a major program to design typical components together with data on the economic and acoustical efficiency of such end items.

Lead and zinc are most often employed where their corrosion resistance characteristics become a major factor in performance. Therefore, their behavior is influenced predominantly by the characteristics of their surfaces. In lead, research has been started at the University of Melbourne on the chemical and metallurgical behavior of the lead surface as a function of atmospheres, corrosive media, the influence of alloying constituents, and temperature. A similar program will be undertaken by the British Non-Ferrous Metals Research Association.

The market for lead tetraethyl is of major significance, yet it is the only major market for lead chemicals outside of the paint and pigment industry. Because of the chemical industry's challenge, three programs of significance have been initiated: one with T.N.O. in Utrecht, Holland another with the Quartermaster Research and Engineering Command of the US Army, and a third with Arthur D. Little Inc. The first two programs cover fundamental research in lead organometallics, the study and synthesis of new lead organometallics. The Arthur D. Little program will take existing lead chemicals, plus the products of the two fundamental programs, and evaluate their application for plastic intermediates for their biological activity, etc.

These are but a few of the many new developments in lead and zinc leading to a growing demand for the metals and an ever increasing need in our present-day technology.

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SECRETARY—R. W. SHEARMAN

ASST. SECRETARY—D. C. JOHNSTON

NEWS OF YOUR PROFESSION

HIGH-VELOCITY DEFORMATION CONFERENCE AT ESTES PARK, COLO., JULY 11-12

Response of Metals to High-Velocity Deformation is the theme of the meeting sponsored by the Physical Metallurgy Committee of The Metallurgical Society. Headquarters for the July 11-12 conference will be the Stanley Hotel in Estes Park, Colo., just 60 mi from Denver.

A total of 16 papers is scheduled for the two-day meeting, plus the usual complement of social activities. The meeting's content will be largely the crystallographic, metallographic, and basic metallurgical phenomena that occur in metals under high strain rate. It will not be concerned with explosive forming methods or engineering. No other such conference is known to be contemplated, and the only previously known one related to the subject was held under the auspices of the Institution of Mechanical Engineers in London, 1957.

The complete conference program appeared on p. 292 of the April issue, but to recap the papers to be given, the titles are as follows:

Survey of Mechanisms Controlling Dislocation Motions Up to Relativistic Speeds . . . On the Role of Dislocations in the Dynamic Behavior of Aluminum Under Impulsive Loading . . . Instrumentation for High Speed Strain Measurement . . . Effect of Grain Size, Rate of Strain, and Neutron Irradiation on the Tensile Strength of Steel . . . Dynamic Stress and Deformation in a Mild Steel at Normal and Low Temperatures . . . Crystallographic Aspects of High-Velocity Deformation of Aluminum Single Crystals . . . Some Fundamental Properties of Shock Waves . . . A Metallurgical Method for Simplifying the Determination of the Hugoniot Curves for Iron Alloys in the Two-Wave Region . . . Dynamic Response of Metals to Shock Waves . . . The Behavior of Iron and Steel Under Impulsive Loading . . . The Behavior of 0.45 and 1.0 pct Carbon Steel Under Impulsive Loading . . . Metallurgical Effects of High Intensity Shock Waves in Metals in I. BCC Metals; and *II. Nickel . . . Shock Wave Effects on Austenitic Maganese Steel . . . Further Metallographic Studies of Metals Subject to Explosive Shock . . . Effects of Explosive Loading on Single Crystals and Polycrystalline Aggregates . . .* and *On the Fracture of Solids Under Impulsive Loading Conditions.*

Advance registration—$15 for AIME members; $20 for non-members—can be made by check payable to **W. C. Leslie, Treasurer,** c/o Dr. W. C. Leslie, E. C. Bain Laboratory for Fundamental Research, U. S. Steel Corp., Monroeville, Pa.

Hotel registrations should be made directly to the Manager, Stanley Hotel, Estes Park, Colo.

German Conference Nov. 2-4 to Discuss Ferrous Metallurgy

A Conference on Ferrous Metallurgy is scheduled for Dusseldorf, Germany, Nov. 2-4. It will honor the 100th anniversary of the Verein Deutscher Eisenhüttenleute.

The Conference will begin with a reception of foreign participants and their wives, as given by the city of Dusseldorf. Thursday, Nov. 3rd, will be devoted to morning and afternoon sessions of all special committees. That evening will see members' meetings and a social gathering. Friday, Nov. 4th, will be devoted to formal sessions and a banquet.

During the week preceding the Conference—Oct. 31 to Nov. 2nd—there is a possibility that a limited number of foreign participants will be able to visit some plants, if requests are made in time. No visits will be scheduled on Nov. 3rd or 4th, however.

For more information, contact Dr. Thomas, c/o Deutscher Eisenhüttenleute, P. O. Box 8209, Dusseldorf, Germany.

Powder Metallurgy Conference to Meet In New York June 13-17

June 13-17 are the dates of the International Powder Metallurgy Conference meeting at the Biltmore Hotel in New York City. Six symposia, combining a total of 39 technical papers, will be staged during the Conference's first two days. Thursday and Friday, June 16th and 17th, will be given over to a choice of five different plant tours covering nine powder metallurgy companies. There will, of course, be the usual array of social activities and banquets. And wives who attend are in for a full slate of sightseeing.

Themes of the symposia are Powder Metallurgy Fundamentals and Theory (whole-day); Dispersion Strengthening; Powder Metallurgy Technology and Methods; and Powder Metallurgy Alloys, Materials, and Applications (whole-day).

The Conference—jointly sponsored by the Metal Powder Industries Federation (MPIF) and the Powder Metallurgy Committee of The Metallurgical Society's Institute of Metals Division—is the first US conference of its kind arranged by non-profit organizations.

Registration fee for members of the MPIF or AIME is $8; $10 for non-members. Rooms at special rates have also been set aside at the Biltmore, and since a large attendance is expected, early registration is advised.

The complete Conference program appeared on pp. 374 to 379 of the May issue.

FALL MEETING

The dates for the Fall Meeting were in error in a letter sent to members of The Metallurgical Society. The correct dates are **Oct. 17-20.** The Meeting headquarters will be the Sheraton Hotel in Philadelphia.

Metallurgy Of Elemental And Compound Semiconductors

Preliminary Conference Program
STATLER HOTEL, BOSTON, AUGUST 29-31

Sponsored by
Semiconductors Committee, Institute of Metals,
Division of The Metallurgical Society, and
Boston Section, AIME

MONDAY, AUGUST 29

Esaki-Tunnel Diodes
9:15 am to 12:30 pm Session I

Opening Remarks—D. C. Jillson, Chairman, Semiconductors Committee.

Materials Requirements for Esaki-Tunnel Diodes:
G. C. Dacey, Bell Telephone Labs.

Heavily Doped Materials for Esaki-Tunnel Diodes:
F. A. Trumbore, Bell Telephone Labs.

Quantitative Aspects of Doping in a Magnetic Crystal Puller:
H. T. Minden, General Telephone and Electronics Labs, Inc.

Impurity Doping for Silicon Tunnel Diodes:
L. V. Lunn, C. T. Sah, and C. S. Roberts, Fairchild Semiconductor Corp.

Growth and Properties of Heavily Doped Germanium Single Crystals:
J. R. Patel, R. F. Tramposch, and A. R. Chaudhuri, Raytheon Co.

Esaki-Tunnel Diodes
2:00 pm to 5:00 pm Session II

Impurities in Gallium Arsenide:
E. O. Johnson, Radio Corp. of America.

Hall Measurements on Tunnel Diode Materials:
T. E. Seidel, Radio Corp. of America.

Preparation of Esaki Diodes from Dendritic Material:
T. P. Brodie and J. P. McKelvey, Westinghouse Electric Corp.

Silicon, Arsenic, Whiskers, and Tunnel Diodes:
N. Holonyak, Jr., D. C. Jillson, I. A. Lesk, and A. I Bevacqua.

Formation of Cubic Silicon Carbide in Silicon Solutions:
A. H. Smith, Raytheon Co.

Growth of III-V Compounds and Alloys from Solution:
E. P. Stambaugh, J. F. Miller, and R. C. Himes, Battelle Memorial Institute.

Solid Solutions of III-V Compounds in Germanium:
J. O. McCaldin, Hughes Aircraft Corp.

TUESDAY, AUGUST 30

Dendritic Growth
9:00 am to 12:30 pm Session III

Fundamentals of Dendritic Growth:
W. A. Tiller, Westinghouse Electric Corp.

Controlled Dendritic Growth of Materials with Zinc-Blende Structures:
H. F. John, Westinghouse Electric Corp.

Dendritic Growth of Semiconductors:
P. J. Holmes, Associated Electric Industries, Ltd., Aldermaston, Berkshire, England.

Solute Segregation in Dendrites of Semiconductors:
S. O'Hara, Westinghouse Electric Corp.

Continuous Growth of Germanium Dendrites:
W. J. Smith, Westinghouse Electric Corp.

Factors Influencing Dendritic Growth in Germanium:
R. S. Wagner, Bell Telephone Labs.

Some Properties of Dendritic Ribbon Crystals of Germanium:
D. C. Jillson, R. E. Hysell, and H. A. Jensen, General Electric Co.

Vapor Growth
2:00 pm to 5:00 pm Session IV

Epitaxial Growth of Silicon P-N Layers from the Vapor Phase:
E. S. Wajda, International Business Machines Corp.

Silicon P-N Junctions for Device Applications by Direct Deposition from a Vapor Phase:
J. E. Allegretti and D. J. Shoambert, Merck and Co. Inc.

Epitaxial Vapor-Growth and Doping of Germanium by a Closed-Cycle Germanium-Iodine Reaction:
J. C. Marinace, W. E. Baker, and D. M. J. Compton, International Business Machines Corp.

Growth Forms and Dislocation Content of Iodide-Grown Germanium Crystals:
H. S. Ingham, Jr., P. J. McDade, and D. M. J. Compton, International Business Machines Corp.

Vapor Phase Growth of Gallium Arsenide Films:
J. K. Clifton and G. A. S. Wingrove, Fairchild Semiconductor Corp.

Growth of Cubic Silicon Carbide Single Crystals by Gaseous Cracking:
R. C. Ellis, Jr., Raytheon Co.

Preparation of Semiconductor Films from Metal-Organic Vapors:
E. H. Tompkins, A. C. Claus, and B. C. Harrison, Armour Research Foundation.

WEDNESDAY, AUGUST 31

Growth of Other Materials
9:00 am to 12:30 pm Session V

Preparation of High-Purity Boron and Crystal Growth by a Crucible-Free Technique:
W. E. Medcalf, K. E. Bean and R. J. Starks, Eagle-Picher Co.

Use of Surface Tension in Pulling Single Crystals of Controlled Dimensions:
G. K. Gaule and J. R. Pastore, U. S. Army Signal Research and Development Lab.

Differential Charge Compensation in Heavily Zinc-Doped GaP-Si Alloys:
E. E. Loebner, I. J. Hegyi, and E. W. Poor, Jr., Radio Corp. of America.

Preparation and Physical Properties of Crystals in the HgTe-CdTe Solid Solution Series:
J. Blair and R. Newnham, Massachusetts Institute of Technology.

X-Ray Investigation of the Perfection of Silicon:
J. R. Patel, R. S. Wagner, and S. Moss, Raytheon Co.

Behavior of Certain Thermoelectric Materials in Nuclear Reactor Environments:
M. Balicki, R. T. Frost and J. C. Corelli, General Electric Co.

Preparation of Single Crystals of Bi_2Te_3 by the Czochralski Method:

Jane Dennis, O. P. Manley, F. Shepherd, and A. Yang, Massachusetts Institute of Technology and Air Force Research Center.

A New Rapid Growth Process for Producing Low Resistivity Textured N- and P-Type Bismuth Telluride:
J. T. Brown, Westinghouse Electric Corp.

Registration

Advance registration material will be sent to most persons reading this announcement. If not received by August 1st, or if additional copies are required, contact *H. E. Bridgers, Bell Telephone Labs., 555 Union Blvd., Allentown, Pa.* Registration fees for the Conference, including the Proceedings Volume, are $10 for AIME members $15 for non-members. Non-members who submit applications for membership prior to or upon registering are eligible for the member rate of $10. Refunds of $5 will be made to non-members joining during the Conference.

Proceedings Volume

The papers and discussions at the Conference will be published as one of the continuing series of METALLURGICAL SOCIETY CONFERENCES, printed by Interscience Publishers, Inc. The volume will be automatically sent registrants without further charge. Every effort will be made to insure prompt publication of the volume so as to increase its usefulness to registrants.

Metallurgical Society President Addresses Western Meetings

Carelton C. Long, President of The Metallurgical Society, was on the go in late April and early May, making the rounds of western meetings.

First stop was the Pacific Northwest Metals and Minerals Conference. Dr. Long addressed the Iron and Steel Session on Thursday, April 28th. The structure and activities of The Metallurgical Society of AIME was the subject of his talk.

Next on the agenda was the May 2nd meeting of the Montana section at the Montana School of Mines in Butte. *Cooperative Research by Metal Trade Associations* was the topic of his talk there.

Dr. Long described the work of the three trade associations serving the lead, zinc, and copper industries. They are, respectively, The Lead Industries Association, The American Zinc Institute, and The Copper Products Development Association.

The work of each of the associations in promoting research and sales and codifying products was described. Dr. Long gave specific examples to show how the trade associations have developed new uses for these metals. Also, how each association has developed programs for communicating with the public through the media of technical pamphlets, posters, books, motion pictures, and statistical information.

Chairman for the May 2nd meeting was George T. Hanson, Anaconda Aluminum Co., Columbia Falls, Mont.

On May 3rd, Dr. Long was many miles to the south speaking before the Utah student section at the University of Utah in Salt Lake City. His topic there was *What An Employer Expects of A Newly Graduated Engineer.* Some of the most important qualifications cited by Dr. Long were an ability to ask questions, and a capacity for good listening.

The Metallurgical Society President also discussed such topics as procedures for getting a job . . . how to get ahead and earn larger salaries . . . the importance of *creative capacity* . . . participation in company communications . . . the cheerful acceptance of any job given . . . the importance of expressing oneself clearly in the English language . . . keeping up with technical literature . . . developing a civic sense . . . and the importance of association with a major technical society. The formal talk provoked a lively discussion.

Norman Weiss served as Chairman of the meeting.

Bar and Allied Products Subject of January Meeting in Pittsburgh

A one-day Conference on Bar and Allied Products has been planned for Pittsburgh on Jan. 18, 1961. Site of the Conference will be the Penn-Sheraton Hotel. The Conference organizers are the Mechanical Working Committee of The Metallurgical Society's Iron and Steel Division and the Pittsburgh section, AIME.

Papers on the surface preparation and rolling of primary products and new developments in processing and testing are planned. Persons interested in presenting papers at this meeting should submit abstracts to *T. E. Dancy, Jones & Laughlin Steel Corp., 900 Agnew Rd., Pittsburgh 30, Pa.*, as soon as possible in order to be considered by the papers committee.

Papers on Magnetism and Magnetic Materials Invited for Conference

The Sixth Annual Conference on Magnetism and Magnetic Materials will meet at the New Yorker Hotel in New York City Nov. 14-17. The Metallurgical Society of AIME is one of the Conference's sponsors. Others are The American Institute of Electrical Engineers, The American Institute of Physics, The Institute of Radio Engineers, and The Office of Naval Research.

Papers are still being accepted for the Conference. Prospective authors should submit titles and abstracts to A. M. Clogston or R. C. Fletcher, Program Chairmen, c/o Bell Telephone Laboratories, Murray Hill, N.J. Deadline is August 26th. Further Conference details may be obtained from L. R. Bickford, Jr., IBM Research Center, Yorktown Heights, N.Y.

AROUND THE SECTIONS

Connecticut section's April 27th meeting brought together three distinguished heads of departments of metallurgy—John Chipman, Massachusetts Institute of Technology; W. D. Robertson, Yale University; and Arthur A. Burr, Rensselaer Polytechnic Institute.

A program on *University Research*, another in the continuing series of meetings on the subject of Research Today was the occasion for the get-together.

The meeting, billed at Past Chairmans Night, was preceded by dinner and socializing at Kaysey's Restaurant in downtown New Haven. The 30 dinner guests moved on to the Hammond Metallurgical Laboratory on the Yale campus, where their number was bolstered by some of the Department's graduate students.

Introduction of past section Chairmen and a short business meeting were on the agenda before the three metallurgy department heads gave descriptions of their respective programs. Section officers for 1960-1961 were also elected. Elected by the casting of a unanimous ballot were Robert S. Bray, Chairman; William R. Johnson, Vice Chairman; Harold Cobb, Secretary; Elmer Barnes, Treasurer; Malcolm F. Burr, Publicity Chairman; Herbert Ball, Membership Chairman; and Bruce Wagner, Member-at-Large.

A Treasurer's report next indicated the healthy state of the Section's coffer. Frank Chudy then appealed to members on behalf of the United Engineering Center's Members' Gifts Campaign. He announced that $2266—or 71 pct of the Section's $3200 quota—has been pledged. He further stated that this figure came from only 21 pct of the membership, and urged the remaining 79 pct to help the Section meet and surmount its goal. The original appeal had been $15 from each member pledged over a three-year period, Mr. Chudy explained. Next it was Dr. Chipman's turn to put in a word for the building fund, as President Gillson's emissary to the Connecticut and Boston sections.

Program Chairman, Bob Bray, then introduced the three metallurgy professors, who in turn diagramed the scope and support of their research programs.

Dr. Robertson of the host school led off the *unrehearsed TV panel* by drawing a three-compound phase diagram which pinpointed the Yale metallurgy department's emphasis in the physics, chemistry, and engineering triumvirate which form the basis of metallurgy. Speaking from the small department standpoint—a faculty of four—Dr. Robertson noted that they stressed physical chemistry, reaching farther toward physics and chemistry than engineering. He claimed that technical obsolescence during the four years of undergraduate study precludes emphasis on application. As to the basis for the Hammond Lab's research, Dr. Robertson said that he and his staff write the proposals for government-sponsored research, keeping uppermost in mind their potential for a graduate thesis. As it was borne out in later discussion, three-fourths of academic research in metallurgy comes from government funding and one-fourth from industry.

Representing the large-staff metallurgy department came Dr. Chipman. His diagramatic approach to MIT's program turned into a full circle encompassing all areas and all disciplines. Dr. Chipman said that in the B.S. program his department strives to teach engineering principles. Casting a baleful eye in the direction of Dr. Robertson, he gently chided emphasis on physics rather than engineering. "We're all engineers," he admonished more than once. He admitted, however, that faculty size limitations do pose their particular problems.

He went on to outline MIT's research activity, encompassing eight areas. The department head said that MIT's government research proposals originate from both the staff and outside. He cited one example of research they have been working on for seven years—the brittleness of ship steel.

Next it was Dr. Burr's turn, he taking the part of the medium-size metallurgy department. Speaking as a representative of a technical institute, he noted that Rensselaer's program falls somewhere between Yale's and MIT's. He said that the program was not as full as MIT's but contained more engineering than Yale's. Selection of research in Rensselaer Polytechnic Institute's Department of Metallurgical Engineering is based on the experience and interest of the staff, he explained. Most of the time Rensselaer staffers originate research proposals, bringing them to agencies, Dr. Burr added.

The end of this meeting brought the Section's formal meeting season to a close. The Section will reconvene in the fall, when the Research Today series will be continued.

St. Louis Section heard the history of the Pea Ridge iron ore body and the formation of a partnership between Bethlehem Steel Co. and St. Joseph Lead Co. during its April 7th meeting. Speaking was Earl L. Bilheimer, resident manager of St. Joseph Lead's Meramec Mining Co. Slides covering the area, equipment, and construction of the project were shown.

Pittsburgh section's IMD group listened to a paper on *Thermal Diffusion in Solid Alloys* during its April 21st meeting. The speaker was Richard A. Oriani, asst. director of physical chemistry, U. S. Steel Corp.'s Fundamental Laboratory. The Webster Hall Hotel meeting was preceded by dinner and cocktails.

Northern Ohio section, NOHC, had its Off-the-Record Meeting March 10th. The Meeting drew 378 registrants, and the number swelled to approximately 415 with the addition of 12 Indian steel engineers and students from local universities who sat in on the afternoon sessions. Dinner at the Pick-Ohio Hotel drew a total of 350 persons.

The Section's next scheduled activity is its Annual golf party at Squaw Creek Country Club, June 8th.

Eastern section, NOHC, is planning its annual golf party for Monday, June 20th. Headquarters for the all-day affair will be the Plymouth Country Club, Plymouth Meeting, Pa. A plant trip to the Phoenix Steel Co. is also on the day's agenda.

In the morning, members and friends have the choice of taking the 9:30 plant trip, playing golf, or indulging in the Club's recreational facilities.

For those who make the plant trip, lunch will be at the Bull Tavern, with John Milos as host. A pay-yourself luncheon will be available at the Plymouth Country Club for those who stay behind.

In the afternoon the following choices are offered: a visit to historic Valley Forge Park, golf at the country club, or swimming, card playing, and so on.

Cleveland section's April 21st meeting was devoted to a talk on *Strengthening of Metals by Stable Dispersoids and Fibers*, as given by John W. Weeton, asst. chief, Alloys and Composite Materials Branch, Materials & Structures div., National Aeronautics and Space Administration. The meeting, appropriately titled NASA Night, was planned by technical chairman John C. Freche, head, Alloys Section and Composite Materials Branch, Materials & Structures div., NASA.

STUDENT NEWS

Polytechnic Inst. of Brooklyn

March was an active month for Brooklyn Poly's AIME-ASM Student chapter. On March 8th, Thomas MacElrath of the Linde Co., div. of Union Carbide Corp., addressed a group of 42 on *Electric Welding Techniques*. His talk was accompanied by a movie on *Sigma Arc Welding*, featuring slow-motion pictures of the deposition of weld metal.

The Chapter's first field trip was held March 16th, with 31 students traveling to the General Electric Co.'s metallurgical facilities at Schenectady, N.Y. Seen were the plant's foundry, metallurgy labs, and atomic power establishment.

Then, on March 22nd a group of 23 heard a talk on *Management's Attitude Toward Research*. Speaking was S. F. Radtke, director of research, American Zinc Institute-Lead Industries Association. Dr. Radtke diagrammed the parameters affecting the establishment of a modern research program during the course of his talk.

Lafayette College

Election of 1960 officers featured the March 31st meeting of the John Markle Society, student chapter at Lafayette College. Also a part of the business meeting was presentation of awards. The Luther F. Witmer Award to the outstanding senior metallurgical engineer was presented to Nicholas Koopman. Alpha Sigma Mu awards were presented to seniors William Triggs, Ralph Mesison, Conrad Kundig, and Koopman.

The technical part of the meeting was composed of a film entitled *The Story of Lead*, borrowed from the US Bureau of Mines.

Case Institute of Technology

The April 5th meeting of the Case Metallurgical Society featured Ed Stonebrook, research metallurgist, Aluminum Co. of America, who talked on applications of aluminum. Then, on April 19th 31 members of the student society viewed the *Face of Red China*, a film borrowed from the Cleveland Library.

The film *Project Mercury* was the drawing card for the May 3rd meeting, which 21 members attended. The film was produced by the National Aeronautics and Space Administration.

NEW STUDENT MEMBERS

Polytechnic Inst. of Brooklyn
Bornstein, Norman S.
Quattrone, Robert
Scolnick, Melvin J.

University of Cincinnati
Moeser, Charles O.

Columbia University
Nikolsky, Leonid E.

Drexel Institute of Technology
Hagarman, Paul O.
Kurisky, George A.
Mannschreck, William A.
Martino, Raymond R.

University of Illinois
Saffiq-Udin Ahmed, A. H.

Kansas University
Brooks, John E.

Lehigh University
Borland, Clifford R.
Notis, Michael R.
Richardson, Wilbert J.

Massachusetts Inst. of Technology
Axelrod, Stephen D.
Bradt, Richard C.
Mravic, Brian
Rasmussen, Jens G.

University of Michigan
Lang, Robert G.
Judd, James C.

Missouri School of Mines
Rose, Robert M.
Skow, R. Patrick

Montana School of Mines
Waters, William C.

Pennsylvania State University
Brown, Richard R.

University of Pittsburgh
Hann, Fred J.

Purdue University
Lannin, Jeffrey
Yaste, John E.

Rensselaer Polytechnic Inst.
Andrews, Henry L.
Arnold, Philip E.
Solomon, Joel L.

South Dakota School of Mines & Tech.
Gorder, Carlton T.

Texas Western College
Coggan, Lyle A.
Everett, Thomas G., Jr.
Johnson, Theodore D.

State College of Washington
Pierson, Jimmie D.

University of Washington
Engdahl, Donald C.

Wayne State University
Creeger, Gordon A.
Moorman, Lewis B., Jr.

Electron Microscope Society Sets Meeting

The Electron Microscope Society of America's 18th Annual Meeting will be held Aug. 29-31 at the Brooks Memorial Union Building, Marquette University, Milwaukee, Wisc.

Three symposia and a special session of short papers on unusual electron microscopic techniques will makeup the Meeting. The titles of the symposia will be The Structure of Teeth and Bone, Recent Developments in Electron Metallography, and Theory and Applications of Electron Diffraction. There will also be extensive scientific and commercial exhibits on display.

Further information about the program may be obtained from the Program Chairman, W. C. Bigelow, Dept. of Chemical and Metallurgical Engineering, University of Michigan, Ann Arbor, Mich. Questions about exhibits and exhibiting should be directed to Stanley Weinreb, Dept. of Anatomy, Marquette University School of Medicine, 516 N. 15th St., Milwaukee 3, Wisc.

Fall Meeting Abstracts

June 29th is the deadline for submission of abstracts to be considered for presentation in IMD-sponsored sessions at the 1960 Fall Meeting of The Metallurgical Society.

In order to be considered for inclusion in the program, each submission must include:

1) A 200-300 word abstract typed double-space on one side of the paper only. (No photographs, figures, tables, or diagrams, please.)

2) Complete mailing address of *each* author on a separate sheet, together with title of paper being submitted.

3) Acknowledgements of research sponsorship, *where applicable*.

All required information and abstracts should be submitted in 3 copies to:
The Metallurgical Society of AIME, IMD Program Committee, 29 W. 39th St., New York 18, N. Y.

Volumes 5, 6, and Plutonium Book Coming

Volumes 5 and 6 of the METALLURGICAL SOCIETY CONFERENCES, plus the transactions of the plutonium metallurgy sessions during the 1959 AIME Annual Meeting are scheduled for publication early this month and next. Volume 5 is **Properties of Elemental and Compound Semiconductors,** edited by Harry C. Gatos, Massachusetts Institute of Technology. The volume represents the papers and discussion of the Conference on the Properties of Elemental and Compound Semiconductors held in Boston Aug. 31-Sept. 2, 1959.

The material of this volume is grouped into five parts: I. Metallurgical and Chemical Aspects; II. Solid State and Surface Reactions; III. Chemical and Lattice Defects; IV. Physical Properties and Device Applications; and V. The Role of Dislocations in Device Properties. Parts I-IV contain the papers presented at the Conference, together with the discussions which followed their presentation. Part V is a record of the panel discussion on the subject indicated. The 352-pp. book is available to AIME members for $6.80; $8.50 to non-members. Non-members should order directly from Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N. Y. (The second conference on Metallurgy of Elemental and Compound Semiconductors will be held at the Statler Hotel in Boston Aug. 29-31. See p. 488 for the preliminary program).

Flat-Rolled Products 2: Semi-Finished and Finished is the sixth volume in the series on METALLURGICAL SOCIETY CONFERENCES. The outgrowth of the Second Annual Mechanical Working Committee Conference on Flat Rolled Products, this book is soon to be available to AIME members for $3.20; $4 to non-members. Registrants for the Conference on which this volume is based will, as usual, received their copies as part of their registration fee.

The contents of this 160 pp. volume, edited by E. W. Earhart and R. D. Hindson, reads: Hot Machine Scarfing of Semi-Finished Carbon Steels . . . Selection of Ingot and Slab Sizes for the Modern Strip Mill . . . Observations on the Scale Structures of Mild Steel Strip . . . Temper Rolling and Its Effect on Stretcher Strain Sensitivity . . . Unitized Automobiles . . . and Processing and Properties of Magnetic Materials.

In his foreword, Michael Tenenbaum, 1959 Chairman of the Iron and Steel Division, has this to say:

"The subject matter of the first two Mechanical Working Committee Conferences has been closely related to the process metallurgy of flat rolled steel products. This should not be construed as a limitation in the scope of subjects to be covered in the annual meetings and special symposia to be arranged in subsequent years. The Committee recognizes that its technical coverage must include scientific and engineering aspects involved in the processing of the full range of steel mill products. This includes the mechanical working processes wherein such products are formed, as well as the methods by which they are treated, coated, and inspected. In its coverage of this broad field, the Committee encourages the generation, publication, and presentation of papers describing engineering developments in the mechanical working field and assumes the responsibility for actively soliciting fundamental contributions from the laboratories, steelworks, and academic institutions."

The Mechanical Working Committee's next scheduled conference will be Jan. 18, 1961, when Bar and Allied Products will be the topic of a meeting in the Penn-Sheraton Hotel in Pittsburgh. (See story, p. 489 for more details).

Introduction to Plutonium Metallurgy 1959 is the title of the third volume soon to be released. Although not a part of the numbered series of conference volumes, publication of this book is made on the basis of interest it should have for nuclear metallurgists and others. The material is drawn from symposia on the extractive and physical metallurgy of plutonium given during the 1959 Annual Meeting. Under the extractive metallurgy titles we find: Alternative Routes for the Conversion of Plutonium Salts to Metal and Their Recovery Problems . . . Calcium Reduction of Plutonium Halides to Metal . . . Preparation of Metallic Plutonium . . . Distribution of Plutonium and Selected Impurity Elements Between Nitrate Solutions and Tri-n-butyl Phosphate . . . The Preparation of Plutonium Halides for Fused Salt Studies . . . and Removal of Fission Product Elements from Plutonium by Liquidation.

The physical metallurgy papers include: Some Principles of the Alloying Behavior of Plutonium . . . The Plutonium-Cerium Diagram . . . Plutonium-Zinc Phase Diagram . . . Metallography of Alpha Plutonium . . . The Etching of Plutonium and Its Alloys by Cathodic Bombardment . . . A Study of the Transformation Kinetics of Alpha, Beta, and Gamma Plutonium . . . Some Expeiments in Zone Refining Plutonium . . . Behavior of Some Delta-Satilized Plutonium Alloys at High Pressure . . . plus an annotated bibliography.

Edited by W. D. Wilkinson, Argonne National Laboratory, the book is tentatively priced at $8 for AIME members; $10 for non-members. The number of pages is not known at this time.

AIME members may order any of these three books from The Metallurgical Society, 29 W. 39th St., New York 18, N. Y. Non-members should order directly through Interscience.

FOR THE FIRST TIME

You can have in one reference book the most up-to-date information on the many new developments in the metallurgy of plutonium. The book is INTRODUCTION to PLUTONIUM METALLURGY 1959. Based on the symposium presented at the 1959 AIME Annual Meeting, it will be published next month. Order your copy now!

The Secretary
The Metallurgical Society
of AIME
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New Section Rebate Plan Adopted for 1961

Editor's Note: A new plan for rebates to local sections has been adopted by the AIME Board and will go into effect in 1961. The plan was formulated by a committee composed of L. E. Elkins, R. V. Pierce, and J. S. Vanick. Following is the complete report of the "Elkins Committee", whose purpose was "to study financial assistance to subsections and the Swan report."

Purpose

This Committee was appointed to study the desirability of financial assistance to Subsections and to study the Swan Report. Concern had been expressed that the program for financial assistance to Sections authorized by the Board of Directors in February 1959, could result in some Sections, particularly with Subsections, dividing in order to get a greater amount of income from dues rebate.

Proposal

This Committee recognized the financial incentive under the authorized program for groups within some large Sections to break off into new Local Sections. The Committee also recognized the record of membership growth and enthusiasm for AIME stimulated in the past by the creation of new Local Sections where professional interest or geographical location prevented proper servicing of the members through existing Local Sections. To preserve the benefits derived by encouraging new Local Sections and at the same time hedge against the risk of exorbitant financial obligation on the part of AIME, a slight modification of the financial assistance program authorized for 1960 has been approved. Pertinent differences of the past, that authorized for 1960, and that authorized for 1961 are set forth in Table I.

Discussion

The Board of Directors has been concerned for several years over the pros and cons of forming numerous small Sections. New Sections initially are formed for one of two reasons: 1) Geographically, AIME members find themselves grouped in such a way that they desire Local Section status separate from some larger geographical area; and 2) Society interest in some geographical areas is so pronounced that there is justification for providing overlying Sections so that petroleum, metals, or mining can each have sectional status.

History has proved that the creation of many of both types of Local Sections has stimulated increased AIME membership. At the same time, the mounting Section delegate expense and the difference in ways this money has been used (as well as the unwieldy size of Section delegate conferences) posed some problems.

To resolve the Section delegate expense problem, the Board of Directors took action at the Feb. 15, 1959, meeting which eliminates direct payment by the Institute for Section delegate expense. This reduction in income to Sections was offset by a new schedule of dues rebate which was intended to direct this portion of the Institute's budget to Sections where the need is greatest; namely, the small Sections as compared to the larger Sections. This action, at least in spirit, seemed to be generally acceptable to most of the Section delegates and to the Board members as a whole.

Nevertheless, it still posed one serious problem: That was relative to the $250 minimum dues rebate that would go to all Local Sections and the lack of direct financing of Subsections.

Formation of New Sections

In the 1960 program there is obviously a strong financial incentive for Subsections, isolated groups, or groups with strong professional interest to petition for Section status. A Subsection that would get no money directly from AIME could petition for Section status and get $250 a year as a minimum dues rebate and 50 per cent of the initiation fee for new members. This would be quite a windfall for groups of 100 or fewer members. If this group spun off from a large Section (leaving 800 or more members in the original Section) the large Section would not lose any dues rebate. The large Section would, however, lose 50 pct of any initiation fee for new members joining the smaller Section. And yet, in many instances, the benefits to be gained by AIME by formation of small Sections override what might be termed "selfish" motives.

Therefore, the problem has been to find a way of preserving the benefits of forming new Local Sections (even if small) without too great a financial burden caused by the $250 minimum rebate. Even though it was recognized that the larger Sections are obligated (and willing) to aid in supporting smaller Sections, the 1960 authorized dues rebate program was believed too conservative for the larger Sections. Also, increased burden to some Sections of financing Subsections might be lessened.

If Sections are formed with 25 to 50 members and then grow to 100 or more, AIME has no problem. If no growth follows the formation of a small Section, AIME has accepted a heavy financial obligation which could be serious if many small Sections stay small.

With all of these factors in mind, the program shown in outline form in Table I was adopted by the AIME Board of Directors on Feb. 14, 1960, to become effective Jan. 1, 1961. Under this program, the membership for each Local Section at the beginning of the calendar year would be the basis for calculating dues rebate and the percentage of initiation fees to be returned to the Local Section.

Table II shows the type of income that would be received from Sections of various sizes under the method of financing used in 1960 and that adopted for 1961. It is noted that the total income to Sections of various sizes (up to 800 members) in 1961 is very close to that employed in 1960. The allowance of $0.50 per member above 800 places the large Sections back in line with the total amount of funds that had been going to them under previous methods of financing. It will be noted, however, that the high return per member in the small Sections (25-75) can only be assured from year to year by strong membership activities.

Large Sections

If a Section with more than 800 members has a Subsection, this Section gets special treatment insofar as the $0.75 dues rebate is concerned. Table II shows a typical example of how this would operate: If a Section has 1,500 members and within that total there are 200 members in one or more Subsections, the Section will get a $0.75 dues rebate for 1000 (800 + 200) and $0.50 for the remaining 500.

It is recognized that Sections financing Subsections have extra financial burdens. This would be true for either professional or geographical Subsections. Therefore, extending the $0.75 dues rebate beyond membership of 800 is believed in order when Sections operate Subsections.

As of Jan. 1, 1960, there were only six Sections that had memberships in excess of 800; namely, Chicago, Gulf Coast, New York, Pittsburgh, San Francisco, and Dallas. Two of these (Pittsburgh and San Francisco) have professional Subsections.

The additional rebate to large Sections having Subsections is not intended to discourage formation of new Local Sections where justified. This is believed important! Building up officers to handle Local Section activities is one mechanism that indirectly supplies many benefits that members receive from AIME membership. This type of decentralized leadership has contributed much to the strength of AIME that is now evidenced. Therefore, it is believed that only when a group petitions for sectional status, and justifies this request to the AIME Board, should it be accorded *direct* financial support through dues rebate and return of all or part of initiation fees from AIME. Subsections that, for one

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reason or another, chose to remain as such, should look to the Section for services intended from dues and initiation fee rebates.

Annual Expense Statements

Submitting annual expense statements showing the source of funds and the type of expenditures would serve two purposes: 1) Offer proof of bona fide efforts to properly service the members of the Local Section; and 2) Supply resource material as to methods used by various Local Sections in securing outside funds. In accordance with the recommendations of the Swan Report, a committee of Board members, Society members, and Section delegates might be charged with the responsibility to review these statements to insure that any valuable information obtained from them can be passed on in a general way to all Local Sections. Furthermore, if some fund-raising practices seemed to be out of line with the philosophy of AIME or the Societies involved, the specific situation and circumstances could be reviewed and, if necessary, Local Sections could be cautioned accordingly. It is doubtful if the risk of Local Sections going askew on fund-raising methods is great enough to endeavor to define a policy for fund-raising. This would have to be sufficiently comprehensive to recognize the widely varying situations and opportunities peculiar to our almost 90 Local Sections.

TABLE I—COMPARISON OF REBATE PROGRAMS OF PAST, 1960 AND 1961

Past	Authorized for 1960	Approved for 1961 — A Slightly Modified Program From That Authorized for 1960
$0.50 dues rebate	$0.75 dues rebate per member up to 800 members, i.e., maximum of $600 to a Section	$0.75 dues rebate per member up to 800 members and $0.50 for all member above 800; except if a Section administrates one or more Subsections the $0.75 dues rebate will apply to a number greater than 800 to the extent that membership in the Subsections comprises or offsets the membership above 800 in the Section, then above that level the $0.50 per member dues rebate will apply.
Minimum per Section $100	Minimum per Section $250	Minimum per Section $4.00 per member or $250 whichever is smaller. Sections with membership between 63 and 333 will all receive a dues rebate of $250.
No maximum dues rebate	$600 maximum dues rebate	No maximum dues rebate per Section
50 per cent of income from initiation fees returned to Section	50 per cent of income from initiation fees returned to Section	100 per cent of income from initiation fees returned to Section until it has 75 corporate members as of the first of the calendar year. Thereafter, 50 per cent.
Travel expense allowed for Section delegate	No travel expense allowed for Section delegate	No travel expense allowed for Section delegates.
Information expenditure sheet submitted by Local Section	Information expenditure sheet submitted by Local Section	Section should submit an annual expense statement showing annual income and expenses, indicating source of funds and type of expenditures.
New Sections authorized by Board of Directors when, according to by-laws, at least 25 members are in the area and 10 have signed a petition and submitted appropriate by-laws and providing existing Section agrees to release of geographical area or from an an overlying Section due to professional interest.	Same as in the past	Same as in the past, except it is recommended that the Board of Directors require that the petitioning Section indicate that in the area to be served there is a potential membership of at least 50 members that can reasonably be achieved in a period of perhaps two or three years. It is intended, however, that each application for sectional status stand on its own and this would not be a rigorous restriction.

TABLE II—COMPARISON OF 1960 AND 1961 METHODS OF INSTITUTE FINANCING OF LOCAL SECTIONS

No. Members in Section	Assumed Members Added Per Year	Section Income From Institute 1960 Method: Dues Rebate	Initiation Fee Rebate*	Total	Section Income From Institute 1961 Method: Dues Rebate	Initiation Fee Rebate*	Total
25	10	$ 250	$ 50	$ 300	$ 100	$ 100	$ 200
50	15	250	75	325	200	150	350
75	20	250	100	350	250	100	350
100	20	250	100	350	250	100	350
150	25	250	125	375	250	125	375
200	25	250	125	375	250	125	375
250	30	250	150	400	250	150	400
300	30	250	150	400	250	150	400
350	35	262	175	437	262	175	437
400	35	300	175	475	300	175	475
600	50	450	250	700	450	250	700
800	65	600	325	925	600	325	925
1000	75	600	375	975	700	375	1075
1500	100	600	500	1100	950	500	1450
1500[1]	100	600	500	1100	1000	500	1500

*Assumes average initiation fee of $10.00 after credit to Junior Membership.

[1]Assumes Section has 200 members in Subsections.

DISTRIBUTION OF SMALL SECTIONS

No	Membership, Jan. 1, 1960	No.	Membership, Jan. 1, 1960
0	0-25	9	75-100
6	25-50	37	100-300
8	50-75	25	300-800
		6	800-or more

New Theory on Semiconductor Crystals Given at N.Y. Meeting

A new theory on the origin of vacancies in semiconductor crystals was expounded by Prof. John N. Hobstetter, University of Pennsylvania, during a speech before the Physical Metallurgy Group of the New York section, April 14th. The talk, entitled *Semiconductor Metallurgy*, was followed with keen interest, and prompted a stimulating discussion.

The background of several investigators' efforts to explain the behavior of the sponges, which play such an important role in the crystals of semiconductors, was first advanced. The idea that vacancy-sponge or vacancy-superlattice structures may form in these crystals was first suggested by Kuhlman - Wilsdorf, and further elaborated upon by Hornstra in his description of the stabilization of sponges in covalent crystals of the diamond type. When two vacancies are third neighbors, a double bond can form between the pair of intervening atoms, thus eliminating a dangling bond at each of the vacancies. Inside the sponge, most dangling bonds will disappear, making the sponge fairly stable through recovering about 20 pct of the vacancy energy.

It now appears that these sponges may well play very important roles in semiconductor crystals and may answer many puzzling problems. For example, Logan found that vacancy-acceptors do not anneal out completely from quenched germanium, but, rather, level off at concentrations characteristic for the annealing temperature. This annealing affect may well be the cause for the nucleation and growth of sponges. Since only the dangling bonds at sponge surfaces exhibit the acceptor property, the surface decreased with increasing spheroidization as the annealing temperature is raised.

Tweet found that in dislocation-free germanium (which should contain no ready vacancy sources) the

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equilibrium vacancy concentration is very quickly established at any temperature—just as if grown-in vacancies were always available. The dissolution of sponges at high temperatures easily accounts for this effect.

Investigations by Patel proved that the upper yield point in dislocation-free germanium is less than the theoretical strength, although the drop to the lower yield is very large and relatively slow.

Thus, Professor Hobstetter proposed that the application of large stresses at the deformation temperature should cause the breaking of the double bonds in sponges by thermal fluctuation, thereby freeing the vacancies. Their local vacancy supersaturation of about 10 pct should, then, lead to their rapid coalescence into large discs, which will collapse to form dislocation sources by the Wilsdorf mechanism. The large, time-dependent yield phenomenon is, thus, explained.

Visible evidence of sponges is suggested by the large (100 μ), round-bottomed pits—different from dislocation pits—that often form on etched surfaces of low-dislocation material. It appears that sponges may also be decoratable with copper or lithium.

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on March 31, 1960, was 33,949; in addition 2,663 Student Members were enrolled.

ADMISSIONS COMMITTEE

L. L. Seigle, Chairman; W. L. Brytczuk; F. B. Foley; T. D. Jones; Harold Margolin; Shadburn Marshall.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Broglie, Francis J., Bethlehem, Pa.
Brown, James W., Pittsburgh, Pa.
Campbell, Charles G., Pueblo, Colo.
Diamond, John W., Fair Oaks, Calif.
Fitzgerald, John J., New York, N. Y.
Gaw, Richard G., Pittsburgh, Pa.
Gilbert, Saul, Monroeville, Pa.
Hinnebusch, Raymond A., Vandergrift, Pa.
Horsman, Don C., Kokomo, Ind.
Houghton, Chris. S., Camillus, N. Y.
Isleib, Charles R., New York, N. Y.
Keckler, Clark G., Bethlehem, Pa.
McGee, Sherwood W., Chicago, Ill.
McGhee, K. Burr, New York, N. Y.
McGill, John W., Homestead, Pa.
Parikh, Niranjan M., Chicago, Ill.
Poliskin, Jacob S., Pittsburgh, Pa.
Pry, Robert H., Schenectady, N. Y.
Ruh, Edwin, Pittsburgh, Pa.
Saarivirta, Matti J., Plainfield, N. J.
Simon, Alan I., Highland Park, Ill.
Sprague, Wesley E., New Britain, Conn.
Tarquinee, Val, The Hague, The Netherlands
Thompson, Mitchell A., Fontana, Calif.
Ullmann, Jacob W., Oak Ridge, Tenn.
Vogt, John R., Cleveland, Ohio
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Associate to Member

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Bigler, Clarke A., Coatesville, Pa.
Dickinson, Clayton D., Bayside, N. Y.
Floridis, Themistocles, Monroeville, Pa.

OBITUARIES

Walter C. Smith, consulting metallurgist with the Cerro De Pasco Corp. of New York, died in Cranford, N. J., April 6th, at the age of 75. An AIME member since 1915, he was employed by De Pasco for 31 years.

J. B. Eldridge, whose career in mining and metallurgy dated from 1898, died in Placerville, Idaho, on Feb. 15th, at the age of 90. He took part in the Klondike rush in 1898, came away from there with a sack of gold dust, and turned to prospecting the Kansas territory. In 1902 he went to central Idaho in exploration for the Independence Mines & Power Co. Mr. Eldrige also worked the Mountain King mine and Mayflower Gold mines in Idaho. He was a long-time chairman of the Idaho Mining Association.

Adam J. Texter, superintendent of the melt department in Firth Sterling Inc.'s McKeesport, Pa., plant died on June 29, 1959, it has been belatedly reported. Mr. Texter, an AIME member since 1946, began his career with Universal-Cyclops Steel Corp. in 1926.

CORRECTION

You can't keep a good man down, so we shouldn't have been too surprised when we got a wire from Foster G. Garrison saying that his reported death (May issue, p. 423) is "false, I repeat, false." Pittsburgh section supplied us with the bogus information, and we are happy to right the wrong. The mixup occurred because Mr. Garrison's name resembles that of the real deceased, Forrest D. Garretson.

NECROLOGY

Date Elected	Name	Date of Death
1921	Angus, D. H.	Feb. 22, 1960
1957	Austin, Gerald F.	Jan. 1, 1960
1956	Brooks, Robert E.	Unknown
1897	Burrall, F. P. (Legion of Honor)	Feb. 11, 1960
1909	Busey, A. P., Jr. (Legion of Honor)	June 22, 1959
1922	Davis, Ira F.	March 19, 1960
1921	Dunn, H. Earl	Feb. 5, 1960
1932	Eldridge, Jas. B.	Feb. 15, 1960
1955	Frensley, T. C.	June 2, 1959
1951	Fullop, Paul	May 27, 1959
1930	Goodale, G. S.	Feb. 20, 1960
1958	Gray, Roger N.	June 14, 1959
1941	Hill, J. Edwin	Jan. 7, 1960
1958	Hirschfeld, G. H.	Dec. 28, 1959
1956	Hosford, Phillip N.	Feb. 23, 1960
1921	Howie, Howard	March 20, 1958
1958	Hutchinson, J. L.	Jan. 7, 1960
1946	Lubrecht, F. S.	Unknown
1927	Marshall, K. L.	Dec. 21, 1959
1936	Matthews, Armstrong	April 2, 1960
1916	Mead, W. J.	Jan. 16, 1960
1955	Patterson, F. E.	Jan. 5, 1960
1946	Petusky, Joseph	Jan. 22, 1960
1943	Platt, F. C.	July 11, 1958
1948	Purvis, D. R.	Unknown
1946	Richards, R. H.	Dec. 20, 1959
1950	Richmond, K. C.	Nov. 23, 1959
1944	Roff, W. Wallace	Jan. 16, 1960
1941	Smith, Gordon C.	Jan. 20, 1960
1915	Smith, Walter C.	April 6, 1960
1946	Texter, Adam J.	June 29, 1959
1935	Ulrich, C. T.	Feb. 28, 1960
1939	Vedder, D. G.	Dec. 8, 1959
1940	Vreeland, G. W.	March 7, 1960

NSF Awards $6500 to Metallurgical Society For Conference Support

The National Science Foundation has granted The Metallurgical Society a total of $6500 toward the sponsorship of two metallurgical conferences. A $3000 award has been made in support of the International Powder Metallurgy Conference meeting at the Biltmore Hotel in New York City from the 13th through 17th of this month. The program for this Conference was published on pp. 374-379 of the May issue.

A $3500 grant will help support the Conference on Response of Materials to High Velocity Deformation, meeting at the Stanley Hotel in Estes Park, Colo., July 11-12. The program for this Conference appeared on p. 292 of the April issue.

France to Hold Meeting on Electrostatic Forces

Physics of Electrostatic Forces and Their Applications is the theme of an international symposium which will take place in Grenoble, France Sept. 27-Oct. 1.

Sponsor of the meeting is the Electrostatic and Metal Physics Laboratory, Centre National de la Recherche Scientifique, Grenoble University.

Coming Events

June 8, Northern Ohio Section NOHC, Golf Party, Squaw Creek Country Club, Youngstown, Ohio.

June 9-10, AIME Columbium Symposium, sponsored by the Hudson-Mohawk section, Hotel Sagamore, Lake George, N. Y.

June 13, Pittsburgh Section, NOHC, Golf Party, Mt. Lebanon Country Club, Pittsburgh.

June 13-15, First International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPIF.

June 18, Cleveland Section, NOHC, Dinner-Dance, Lake Shore Hotel, Cleveland.

June 20, Eastern Section, NOHC, Golf Party and plant trip, Plymouth Country Club, Plymouth Meeting, Pa.

June 20-24, American Society for Engineering Education, 68th annual convention, Purdue University, Lafayette, Ind.

June 26-July 1, American Society for Testing Materials, Annual Meeting and apparatus exhibit, Chalfonte-Haddon Hall, Atlantic City, N. J.

July 11-12, AIME Conference on the Response of Materials to High-Velocity Deformation, Estes Park, Colo.

Sept. 1, Chicago Section, NOHC, Golf Outing, Gleneagles Country Club, Chicago.

Sept. 15-16, Eighth Annual Engineering Management Conference, Morrison Hotel, Chicago.

Sept. 19-20, 58th Fall Meeting, Steel Founders' Society of America, The Homestead, Hot Springs, Va.

Sept. 23-24, Southern Ohio Section, NOHC, 24th Annual Technical Conference, Deshler, Hilton Hotel, Columbus.

Oct. 3, Chicago Section, NOHC, Fall Dinner Meeting, Phil Smidt's Restaurant, Hammond, Ind.

Oct. 5-7, Rocky Mt. Minerals Conference, Newhouse Hotel, Salt Lake City.

Oct. 12-13, Seventh National Symposium, American Vacuum Society, Cleveland-Sheraton Hotel, Cleveland.

Oct. 13-14, Southwestern Section, NOHC, Fall Meeting, Statler-Hilton Hotel, Dallas.

Oct. 14, Eastern Section, NOHC, 14th Annual Conference, Warwick Hotel, Philadelphia.

Oct. 17-18, Annual Convention, The Magnesium Association, Pick Carter Hotel, Cleveland.

Oct. 17-20, Fall Meeting of The Metallurgical Society of AIME, Sheraton Hotel, Philadelphia.

Nov. 7, Pittsburgh Section, NOHC, 15th Annual Off-the-Record Meeting, Penn-Sheraton Hotel, Pittsburgh.

Jan. 18, 1961, Conference on Bar and Allied Products, sponsored by Mechanical Working Committee of The Metallurgical Society, Penn-Sheraton Hotel, Pittsburgh.

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